A RAND NOTE

SCIENTIFIC AND TECHNICAL INFORMATION TRANSFER: ISSUES AND OPTIONS

Tora K. Bikson, Barbara E. Quint, Leland L. Johnson

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PREFACE

This Note describes a study funded under Contract PRA-84-00689 with the Division of Policy Research and Analysis (PRA) of the National Science Foundation (NSF). The purpose of the project is to identify and assess ways to improve the transfer to potential users of knowledge generated by federally funded research in science and technology. To accomplish this purpose, the study examines problems of information quality control and processes by which scientific and technical knowledge is or could be tailored and packaged for users. It draws heavily from the literature listed in the bibliography and from informal telephone conversations with federal officials, industrial users, information producers, and others. The study includes an overview and evaluation of current federal policies and practices, and an assessment of alternative policy options, especially as they may relate to the NSF. Appendixes suggest future directions for research in dissemination policy and present a history of the evolution of relevant federal policies and milestones.

In view of the two-month duration of the study, this report does not contain a formal evaluation of current policies and practices or a detailed analysis of the relative merits of the options presented. Nor does it formulate a comprehensive plan that recommends and supports remedial actions. Rather, its intent is to provide a framework for longer term research and analysis needed in this field.

Among the actions feasible today, current computer network technology could be used to link the nation's scientific community and thereby substantially augment the information transfer process. The technology-intensive options discussed here move in this direction.

SUMMARY

In this study, we consider ways to more effectively transfer to potential users the knowledge produced by federally funded research in science and technology. Federal policymakers have been concerned that the information created through the billions of dollars spent annually by the federal government is not well utilized because of inadequacies in information transfer between the research and user communities.

Recent literature suggests a number of problems contributing to this concern. First, the very low level of support for knowledge transfer in comparison to knowledge production suggests that dissemination efforts are not viewed as an important component of the R&D process. Second, there are mounting reports from users about difficulties in getting appropriate information in forms useful for problem-solving and decision-making. Third, rapid advances in many areas of science and technology (e.g., biotechnology, computer science) can be fully exploited only if they are quickly translated into further research and application. Such translation requires multidisciplinary, problem-focused communication of scientific information. Traditional transfer mechanisms do not provide that kind of communication. Finally, while the United States continues to be seen as dominant in basic research and development, concerns have arisen that foreign competitors may be better able to apply the results.

The federal government has no coherent, centrally organized, or systematically designed approach to deal with disseminating information created by the basic research community. Approaches to information transfer vary considerably from agency to agency, and within any given agency they have changed significantly over time. These variations have reflected changes in society's attitudes toward science and technology, differences between agencies in how they view their mission, and budgetary opportunities and constraints.

To date, federal agencies have attempted to increase the flow of information chiefly by improving its availability. Agencies have provided support for publication of results in refereed scientific and

technical journals and have sponsored technical reports as a means of quickly disseminating detailed research results. More recently, research-funding agencies and federal information clearinghouses have created fully indexed and abstracted bibliographic databases with online search capabilities. Many government information services have coordinated their efforts with the private sector, particularly with search services run by professional societies.

While some problems remain in assuring the availability of information, federal efforts in this regard have been largely successful. As a result, applied scientists, decisionmakers, and other information users are now faced with an enormous quantity of potentially pertinent research results available in published form and through online services.

However, two problems remain. First, mechanisms are inadequate to help the user assess the quality of available information. Second, the characteristics of actual usage behavior are not sufficiently taken into account, so that retrieval of relevant information in forms useful for application is impaired. Difficulties include the lack of interactive knowledge transfer systems and "cultural" differences between information producers and potential users.

Our literature review and informal discussions with knowledgeable individuals suggest that users rely on two major systems for acquiring scientific and technical information: formal document distribution and informal contacts with colleagues. Formal search services often comprehensively retrieve voluminous materials, but they may fail to identify those of greatest significance. The interactive and informal collegial system is more timely in providing information about current research and its potential significance and is therefore better focused on user needs. But it is not necessarily comprehensive, since individuals are unaware of information resources that do not enter their collegial networks. However, formal and informal systems do complement each other. For example, colleagues are often used as pointers to the published literature; and, for those entering a new subject field, the literature can provide names to contact for referral to more recent work.

In sum, a need exists for more interactive, user-guided information transfer. Passive access to voluminous stores of textual and numeric data does little to promote timely, selective retrieval and application of high-quality R&D results. Therefore, we propose a number of options for improving information transfer in which the emphasis is on increasing the selectivity and user-responsiveness of existing formal dissemination systems and on coupling them more closely to informal systems.

- *Technology-Intensive Options*--These alternatives take advantage of the special properties of interactive computer and communications technologies. They include:
  - Experimental programs using electronic interactive networks to encourage (a) self-configured groups to pass on significant new research findings and in other ways to carry on functions now performed by informal contact circles; (b) potential users to remain in contact with researchers throughout the course of the project; (c) more extended information research sharing, such as exchange of primary data or preprints; and (d) interconnection of networks for a national decentralized information sharing capability.
  - Experimental programs to support the design and development of more flexible and powerful user-guided methods for retrieving and examining highly structured textual and numerical data bases.
- *Supply Side Options*--These would seek to improve dissemination processes from the information supply side, either with or without electronic technology. They include:
  - Improvements in the organization of information by (a) providing abstracts with more complete research information, (b) organizing information by clusters through use of citation indexes and current bibliometric techniques; (c) organizing abstracts and key words "conceptually," with terms from different

disciplines serving as pointers to common knowledge domains.

-- Improvements in the quality of data, through broader use of internationally accepted standards of evaluation and other mechanisms.

-- Greater use of information intermediaries, including encouraging representatives of promising research projects to provide results and technical assistance to potential users.

- *User-Focused Options*--These are directed to strengthening the ability of users themselves to access and evaluate information. They include:

  -- Building user skills to seek out and find relevant information sources, through development of appropriate curricula in educational institutions and special assistance to small businesses and local government agencies.

  -- Programs to encourage the direct participation of users in the information transfer process, by relying on user feedback and other methods during the course of research projects.

  -- Collaborative research programs involving government, industry and universities to provide potential users with opportunities for interaction throughout the life of a research effort to increase the utility of the results.

We suggest four areas for further study. First, choosing wisely among these options will require a systematic evaluation based on technological, economic, and institutional considerations, and an analysis of the roles to be played by the public and private sectors. Second, to ensure that federal information transfer policy meets the evolving needs of users will require further research to assess the potential of new, especially interactive, technologies. Third, the regulatory and legal environment, including the effects of copyright and antitrust considerations, merits continuing investigation. Fourth, the

effects of international information flow and the experiences of other nations in implementing information transfer policies might shed light on problems and opportunities in the United States.

During the course of our work, we have become convinced that two sorts of future research are important. First, policy research in the four areas we have outlined is needed to assess the context in which any future options will be implemented. Second, exploratory research and development is needed to take advantage of the potential inherent in interactive information technology for the improvement of scientific and technical knowledge transfer.

ACKNOWLEDGMENTS

Several of our colleagues at Rand--Vivian J. Arterbery, Norman Z. Shapiro, Lee R. Talbert and Willis Ware--contributed significantly to this report. We benefited greatly from their suggestions as to what direction our research should take and from their knowledge of past and present information transfer systems and technologies. We also learned much from the information producers and users who generously took the time to talk to us about their experiences with current information transfer procedures and to offer suggestions for improvements.

We appreciate the thoughtful review afforded us by Robert Hays of the University of California, Los Angeles. His comments were quite helpful in the preparation of our final Note.

This Note has benefited substantially from the involvement of Rand communications analysts James Chiesa and Mary Vaiana, who were responsible for ensuring its intelligibility to a broad audience. Mr. Chiesa coordinated our individual contributions beginning with the earliest drafts. Dr. Vaiana extensively revised Appendix B. We also thank Patricia G. Bedrosian, who edited the final Note.

The Note as a whole, of course, remains the responsibility of the authors.

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TABLE

I. INTRODUCTION

In this study, we consider how to transfer more effectively to potential users the scientific and technical knowledge produced by federally funded research and development. Federal policymakers have been concerned that the information created through the billions of dollars spent annually by the federal government is not well utilized because the transfer process between the research and user community is inadequate.

Recent literature suggests a number of problems contributing to the concern over shortcomings in the information transfer process. First, the very low level of support for knowledge transfer in comparison to knowledge production suggests that dissemination efforts are not viewed as an important component of the research and development (R&D) process. Second, there are mounting reports from users about difficulties in getting appropriate information in forms useful for problem-solving and decisionmaking. Further, rapid advances in many areas of science and technology (e.g., biotechnology, computer science) can be fully exploited only if they are quickly translated into further research and application. Such translation requires multidisciplinary, problem-focused communication of scientific information. Traditional subject-focused transfer mechanisms do not provide that kind of communication. Finally, while the United States continues to be seen as dominant in basic research and development, concerns have arisen that foreign competitors may be better able to apply the results.

To date, inadequacies in the information transfer process have fallen into three categories. The first is in information *availability*--placing research results and conclusions in media intended to be accessible to the user community at large. Because information availability is of such obvious importance, it has been discussed extensively in the literature and promoted through federal policy. In response, many databases of varying utility have been created for storage, search, and retrieval of scientific and technical information. Consequently, inadequacies in information availability have been largely rectified.

The second category of shortcomings are those in *quality assurance*--enhancing the ability of users to evaluate the scientific merit of information they receive. Here concerns focus on the accuracy of primary data and the validity and scope of conclusions drawn from them. The rudimentary and restricted nature of current quality assurance efforts compromises the abilities of scientists and engineers to retrieve sound information from the vast quantities of available data and to build on what others have learned.

The third category is *user-responsiveness*--organizing and communicating information in ways that take into account the characteristics of potential users and make available information more useful and easier to find. Problems arise in part because of the lack of an interdisciplinary information structure and of a language common to information producers and users, and in part because of the lack of an interactive knowledge transfer system.

Because so much attention has been devoted to information availability, chiefly concerned with questions of access, we will concentrate on the second and third categories, which are critically important and yet have received rather little attention.

METHODOLOGY

This study draws primarily from two sources:

- An extensive survey of the literature, including items listed in the bibliography.
- Telephone or face-to-face discussions with knowledgeable individuals, including federal information managers, university professors or senior scientists in research institutions, executive-level representatives of information-using industries, representatives of firms in the information supply industry, senior staff in government funding agencies, and librarians.

DEFINITIONS OF KEY TERMS

"Scientific and technical" information includes new knowledge generated by R&D activities; it may appear as text, numeric data, models, proofs, prototypes, and the like. We are concerned in this study with nonproprietary information that originates from R&D.

"Information producers" or "suppliers" are those who carry out R&D activities. In the main, these activities have been conducted by universities, research institutes, and R&D divisions of major corporations.

"Information users" or "consumers" constitute a heterogeneous and potentially enormous population. For purposes of this study the user population is divided into four categories:

- The research community itself, as it builds new efforts on the results of previous research and development.
- Government at all levels, as it relies on scientific and technical information to support decisionmaking.
- Industry, as it applies scientific and technical knowledge to the development of new products and processes and to the improvement of extant ones.
- The general public, as it brings disseminated information to bear on a range of professional, social and personal issues.

In this study, we consider information transfer to the first three groups. The interests and requirements of the general public are much more varied than those of the other groups and would merit a separate study to be treated adequately.

"Information media" are the material or technical means by which R&D results are expressed. Traditionally, print media have been used to convey "primary" information products such as research reports, journal articles, and monographs, as well as "secondary" products such as review articles, handbooks, and bibliographies. In recent years, electronic storage has been increasingly employed, particularly for secondary products such as bibliographies, abstracts and indexes. Finally, people themselves should be regarded as media; a great deal of scientific and

technical information is communicated in conferences and classrooms, and via collegial contacts and manpower flow.

"Transfer" or "dissemination" refers to efforts to move the products of R&D from sources to users. The objective is knowledge utilization: the translation of scientific and technical information into new research and development, industrial process or product applications, and informed policy decisions. Concerns about the adequacy of information transfer or dissemination encompass the three components noted above--availability, quality assurance, and user responsiveness.

ORGANIZATION OF THIS NOTE

Section II provides an overview and evaluation of current federal policies. In Section III we discuss options for improving the transfer of scientific and technical information, along with the merits of those options. Appendix A contains suggestions for future research in dissemination policy, including a set of illustrative criteria for formally evaluating current programs and future options. Appendix B describes the history of past federal policies relating to information availability, quality assurance, and responsiveness to the user environment. Appendix C lists important milestones in the history of information poilcy.

II. OVERVIEW AND EVALUATION OF CURRENT FEDERAL POLICIES

The literature review and discussions conducted as part of this study suggest that information users rely on two major systems for acquiring scientific and technical information: collegial contact networks and formal document distribution (cf. Cronin, 1982; Gerstenfeld and Berger, 1980). Peer interactions have assumed increasing importance for information transfer as research documents and retrieval mechanisms have proliferated. Formal search services often retrieve a lot of material but fail to indicate what is of greatest significance. However, formal and informal systems do complement each other. For example, colleagues are often used as pointers to the published literature, and for those entering a new subject field, the literature can provide names to contact for referral to more recent work. Formal documents yield a comprehensive historical archive of findings, while collegial interactions are better sources of information about current research and its potential application.

This section summarizes the status and achievements of some of the more formal information transfer systems that federal policies encourage or rely on. Many problems remain with formal systems, and the difficulties informal systems face in filling the gap are also assessed. Information policies and practices are evaluated in terms of the extent to which they assure availability, enable quality assessment, and respond actively to the needs of users.

AVAILABILITY ASSURANCE

Status and Achievements

The two primary formats for release of federal research results are the scientific or technical journal and the technical report. The form chosen depends on the nature of the funding agency and the tradition of the discipline in which research is funded. NSF, for example, serves the scientific community primarily through support of basic research. Its awards often go to investigators in academic research organizations.

Similarly, NIH operates within the long-established traditions of the biomedical research discipline. Both agencies prefer the scientific journal as the instrument for reaching their audiences, although they also produce a substantial number of technical reports.

The major mission-oriented agencies like the Department of Energy, the National Aeronautics and Space Administration, and the Department of Defense contract with large private sector organizations as well as with universities and small businesses. They focus on more specific problems with heavier technical emphasis. Traditionally, the government report serves them as both the releasing mechanism and a contractual record. Technical reports play an important role in providing the details of procedures and results. Under the pressure of a steadily increasing research volume and rising publication costs, journal publishers usually do not publish detailed information on experimental design, test instrumentation, or experimental findings necessary for data evaluation. Technical reports have no space limits and often serve as a permanent record of project activities and results.

Most of the large federal information services, such as the National Technical Information Service or the Department of Energy's Technical Information Center, have developed in part to archive and disseminate technical report literature. These services are thus analogous to those provided by traditional scientific bibliographic and document delivery channels for the scientific journal and other refereed sources. Through these functions, mission agencies have pioneered the development of computerized information handling and retrieval systems. Many of these systems include large, abstracted files of the refereed journal and book literature as well. The justification for these government services in areas already served by the private sector--besides the fact that so much federal research is published in journals and books--has been the need to collect mission-oriented literature in one place.

Current transfer policies and practices are largely successful at making scientific and technical information available. Research findings are published, indexed, and abstracted. Publishers, government central depositories, and libraries supply documents on request. Abstracts and indexes have proliferated. Many of them have been put

online and are available worldwide. Librarians and specialists in using online search services take advantage of these systems to locate materials requested by users.

It is, of course, never certain that all research is reported. For example, several persons who took part in our discussions mentioned difficulties locating government reports to which they had found references. However, in view of the strong incentives for scientists to gain recognition for their work (Glaser, 1980b), the general belief is that all significant results get into publication. The consensus from sources we reviewed is that the United States is exceedingly rich in scientific and technical literature and that bibliographic search services, although not fully perfected, have proved their utility in "making a first pass through the information morass" (Lide, 1981; cf. Surprenant, 1982). Appendix B presents a more thorough description of the evolution of federal policies and practices in the area of information availability.

Problems

Nonetheless, a number of problems remain in assuring the availability of scientific and technical information. We have identified five principal ones:

- Many potential users are unaware of much of the information available to them.
- Many potential users are discouraged by the complexity and cost of obtaining information from abstracting and indexing services.
- Dissemination of research products is narrow.
- Formal information transfer systems are not timely enough.
- The continuity of abstracting and indexing systems is threatened by budgetary constraints.

Lack of Awareness. A General Accounting Office survey of managers in government information centers revealed that 63 percent knew about scientific and technical databases duplicating or overlapping their own. The report attributes this condition in part to lack of

awareness of existing databases when creating new ones (GAO, 1979; David, 1980). Further, Robbin (1981), Sprehe (1981), and others have found that the federal statistical system, which contains census and health data, is seriously underutilized both inside and outside the federal government, primarily because of the lack of information about available databases. Agency personnel who work with data users report that "for every actual data user they encounter they find many others who need Federal statistics but are unaware that they are available from the Federal Government" (Robbin, 1981) or else are unable to find out where the information exists (GAO, 1979). Finally, it is likely that small firms and local government agencies are at a disadvantage in obtaining scientific and technical information; moreover, research suggests they are in the main unaware of the serious information gap they face (Streetman, 1979; Rothwell, 1979).

System Complexity and Cost. Several sources attest to the burgeoning complexity and cost of the abstracting and indexing systems created to make information retrieval simpler and easier.

- Addressing the American Chemical Society in 1976, Graham pointed out that a *Chemical Abstracts* subscription cost about $3500 and included over 450,000 items per year. In 1950, the cost had been about $300 a year for 50,000 abstracts. By now, a *Chemical Abstracts* subscription costs $62,000 annually and includes 34,000 new items each month. Such changes have required users to dramatically alter their strategies for becoming or staying well informed in a field.
- In 1975, the Human Interaction Research Institute published a guide to information sources in the mental health field. It described 26 different search services, 20 separate indexes to the periodical literature, and 25 reviews (digests, newsletters, journals) for keeping current. A foreword by the chief of mental-health services development at NIMH commented, "Most of us on the policy and practice side are at least vaguely aware that there are ways to reach into the stockpile of information. We mumble the acronyms and alphabet letters of retrieval resources. But how remote and unavailable they often remain."

- Speaking for government administrators, McGowan and Loveless (1981) state, "Public agencies now find themselves...trying to hold the line on service costs while incurring additional expenses for gathering and utilizing information." Concurring, Bozeman and Cole (1982) note that scientific and technical information is voluminous, fragmented, conflicting, and obscure. The costs of access for public managers, in terms of time and effort as well as budget, "are such that a common 'solution' is simply to ignore relevant [scientific and technical] information."

Consistency, clarity, and appropriateness of key words and formats for searching bibliographic databases are mentioned as serious problems (e.g., Wilkin, 1974; Robbin, 1981). For example, in a large-scale survey of engineers and scientists employed at five major U.S. corporations, nearly half the respondents mentioned difficulties with search formats, retrieval structures, ability to use key words to get desired information, and other systems access issues (Gerstenfeld and Berger, 1980). As Lide notes, with bibliographic systems, "a user must learn the language and protocols peculiar to each service" (1981). Other problems arise in relation to abstracts. Sometimes they are not available at all, and in other instances they are so incomplete as to be of little more value than the title itself in indicating what kind of information is available in the indexed material (Thomas, 1982). More careful attention to abstracting by substantively trained individuals was recommended in several of our telephone discussions.

Obtaining and using numeric databases pose "a monumental challenge" to the scientist or engineer (Hawkins, 1980). For machine-readable numeric databases, important obstacles to availability include complex file structures, varied formats, and the need to write the data to specifications for a particular user environment (Lide, 1981); such difficulties are detailed in user studies conducted by Robbin (1981) and David (1980). Bibliographic search services can provide only limited assistance in locating uncompiled data, because the existence of the data typically is not mentioned in the abstract of a paper and authors

do not know how to cite machine-readable files (Robbin, 1981; Hawkins, 1980). Consequently, uncompiled data sources are often learned of only through informal collegial contacts.

To take advantage of online information systems, the user also has to be assured of the following:

- Availability of a computer terminal.
- Adequate connect time.
- Subscriptions to an array of bibliographic services.
- Skill in using the services (either directly or via an information professional).
- Ability to acquire an item of information once it has been identified.
- Funds to cover the expenses that these efforts entail (in labor, equipment, and services). Declining hardware costs ameliorate some of these problems, but start-up expenditures and labor intensive services remain serious issues.

All of these requirements, together with system shortcomings, constitute a formidable set of access limitations for many potential users of the body of scientific and technical information that is, in principle, publicly available.

Narrowness of Dissemination. Research results tend to be disseminated within small, homogeneous audiences (Bozeman and Cole, 1982) or, as one knowledge transfer expert told us, within scientific and technical subdisciplines. The reasons for this are fairly clear. First, formal information transfer channels--including both primary product distribution and secondary information resources--tend to be organized along traditional disciplinary lines (Tornatzky et al., 1983; Bikson, 1980). Between-group differences in language, norms, and values create communication barriers often analogized to cultural differences (e.g., Rich, 1981). Second, collegial contact networks--which in practice seem to constitute the single most important source of referrals to extant information--are also organized along disciplinary lines (e.g., Cronin, 1982). Together, the two systems make for effective information dissemination within fields of inquiry. However,

dissemination across disciplines does not occur readily, and transfer of information from academic sources to nonacademic audiences is even more impaired (Tornatzky et al., 1983).

Sometimes dissemination systems work within boundaries even more restricted than those of a subdiscipline. For example, technical reports produced by private laboratories usually receive no circulation outside the sponsoring organization. Reports produced within academic or public research institutes may receive wide initial distribution but rarely enter formal channels for archiving and future delivery (Rossmassler and Watson, 1980).

Further, attempts to broaden dissemination often fail if user needs are not taken into account. One-way, untargeted distribution efforts may only result in the accumulation of unused materials at the receiving end (cf. Rich, 1981; Bikson, 1980). Many of the persons with whom we spoke said this was a common fate for unsolicited reports, which seemed to arrive "in truckloads" and were quickly shelved. We found no studies that reported the proportion of potential users of documents who in fact used them--clearly a difficult estimation task (cf. Robbin, 1981).

Tardiness. A number of studies have demonstrated that information potentially available in the early stages of projects is often not found until too late to be useful (cf. Thomas, 1982). However, what is timely has been found to vary depending on the nature of the information need. It is generally agreed that, for users who are themselves engaged in research and development, the results of others' work often help them improve their own conceptualizations and can be of value even very late in a project. On the other hand, for users who are engaged in application or administration, information must be acquired very early if it is to be helpful (cf. Bozeman and Cole, 1982; Gerstenfeld and Berger, 1980). While computer-based methods have helped to expedite publication and updating of information as well as its location and retrieval, the process typically does not move rapidly enough to meet the needs of applied scientists or decisionmakers. Reporting, publishing, abstracting, and indexing take a considerable amount of time (Adam, 1975). Thus, informal contact networks are invoked when information needs are immediate. By these channels, users receive preprints of reports and learn the most recent results of relevant work

in progress. Timeliness, then, is a criterion more often met by informal than by formal information transfer procedures.

Threats to Continuity. Traditional scientific journals provide continuous access to research knowledge. Continuity of access via secondary information sources and services is subject to several constraints. The first is the fact that information predating the initial coverage dates of present bibliographic databases can be difficult to find. Second, many sources have called attention to the uncertainty and changeability of the information policy environment of which dissemination processes are a part (e.g., Nason, 1979; Gibbons and Guemmett, 1979; National Academy of Engineers, 1981). Policy variability creates planning problems both for information service providers and for potential users.

Most important, however, are curtailments of services, such as the termination of the former Smithsonian Scientific Information Exchange and the earlier Office of Scientific Information Services. It has recently been argued that federal information agencies provide tax-supported, underpriced services that could be more efficiently and fairly supplied by the private sector, with the users paying full costs. Some federal databases do compete with private sector products, and commercial search services have sometimes bought federal databases only to find it difficult to sell what the federal services price so low. The distribution of responsibilities between the private sector (for-profit and not-for-profit) and the public sector, as well as marketing philosophies for federal information, remain unresolved.

In moving toward a resolution, it is important to recognize that the private sector plays key roles, especially in providing quality assurance and information tailored to user needs. In evaluating current programs and future options, as discussed in Appendix A, careful attention should be paid to roles the federal government might play in strengthening or supplementing activities in the private sector. If an orderly transfer of responsibilities is not arranged, discontinuation of federal services could result in important loss of access to research information.

QUALITY ASSURANCE

Status and Achievements

The historical approach to quality control of primary literature has been peer review. Federal research results published in scientific journals enjoy the benefits of their peer review process, and the professional societies that sponsor the journals are regarded as doing a creditable job of substantive evaluation (e.g., Abelson, 1980; Bozeman and Kim, 1981). Besides the reputation of the journal itself, users also treat the reputation of laboratories or institutions responsible for primary research products as indicators of their quality. Further, if they are available, scientific review articles are regarded as important evaluative syntheses of primary knowledge within a subdiscipline (Glaser, 1980; Huisman and Koster, 1978/79; Branscomb, 1968). Because such efforts are costly and time-consuming but receive less recognition than primary scholarship, they are not widespread (several discussants recommended greater federal agency support for critical reviews). Results published in technical reports do not receive final peer review, although the research they report may be reviewed in progress (Passman, 1969).

Outside of peer review, efforts at quality control or evaluation are limited. Some information users take advantage of citation indexes from the Institute for Scientific Information to measure the impact of published work. In recent years, the Institute has established new databases tracing frontier research in biomedicine, geosciences, and mathematics through groups of key research pieces. Newer literature is measured and weighted by the number of key references in an area cited.

Online systems have made some quality assurance problems with numeric data more tractable; for example, storage and updating is vastly more efficient, and computerized cleaning procedures can be employed. Coupling these services with online retrieval and manipulation by users could expedite the dissemination of high quality scientific data (David, 1980; Hawkins, 1980; Golashvili, 1973); however, such capabilities have yet to be designed and implemented. In the meantime, numeric information systems that evaluate and repackage research data facilitate the use of data beyond the purposes for which it was originally

collected. Although numeric databases constitute only a small fraction of scientific and technical information, their potential utility is extremely high both for the direct answering of factual questions and for the testing of hypotheses through secondary analysis. But for extant data to serve these purposes, strong quality assurance is needed.

The CODATA classification scheme yields three broad categories of numeric data that provide a foundation for quality assessment: measured properties of well-defined systems (e.g., most chemical properties data); observational or environmental data (e.g., seismographic data); and statistical data (e.g., epidemiological records). There are clear standards for the production of reliable measures within well-defined systems of properties, and accepted approaches to quality control of observational/environmental data through control and documentation of measuring instruments and procedures. Quality control of statistical data is more difficult, and there is not widespread agreement as to what it entails (Lide, 1981). Consequently, quality assurance through use of evaluated databases and information analysis centers is limited to some subsets of materials properties data.

Data evaluation projects require coordinated input from many sources. Most projects to improve the quality of scientific and technical data involve a combination of players -- government, industry, professional societies, universities, and often international institutions. In the United States, the leadership role in government efforts is played by the National Academy of Science's Numerical Data Advisory Board, representing the U.S. in CODATA. The National Bureau of Standards' Office of Standard Reference Data supports a network of 25 data evaluation centers. Professional societies such as the American Institute of Chemical Engineers and trade associations such as the American Petroleum Institute also support some data evaluation centers. Federal funding for information analysis centers (IACs), where some data evaluation is carried out, has waned since the 1960s when most of them were established. Industry associations still support some IACs. Some firms have established data collection and evaluation centers, for example, General Electric's Electronic Materials Properties Information Center (EMPIS).

The opportunities offered by computer technology make expanded data evaluation efforts more feasible and more attractive. New developments in computer-aided design and manufacture require reliable data for incorporation into design analysis programs. The Metals Properties Council is supporting the development of a National Cooperative Materials Property Data Network. Still, these subfields comprise only a minute sector of the area of materials properties, and the latter account for only a small fraction of the data produced by scientific research. Appendix B discusses the historical background of federal policies and practices directed toward assuring the quality of R&D information products.

Problems

According to the literature we reviewed and the discussions in which we participated, information users regard themselves as the ideal evaluators of primary research products in their fields of expertise. This ideal, however, is often infeasible. Many of the most challenging and promising opportunities for the application of research arise from work performed outside the potential user's discipline (McGowan and Loveless, 1981). For primary products outside users' areas of competence, it is difficult to distinguish good research from literature that sounds "science-like" (Bozeman and Bozeman, 1981); the latter, in fact, may well be more readable (Beyer and Trice, 1982). But the most important obstacle to user evaluation is the sheer quantity of information produced. While current dissemination policies and practices increase the amount of scientific and technical information available to potential users, they complicate the evaluation of its quality.

- According to Lide (1981), conflicts and inconsistencies in available information often delay decisions that have a strong technical component or else result in decisions being made on a grossly inadequate basis. "At times the sheer mass of data tends to discourage a logical approach to decisionmaking."

- Echoing this view from the public-administration perspective, Bozeman and Cole (1982) point out that "the hue and cry about information overload" has not prevented policymakers from contending that they lack sufficient good information on which to base decisions.
- Many discussants noted that for any given subject field the ratio of useful to useless information was likely to be very small. In a similar vein, Surprenant (1982) comments that American society "has moved from being information poor through information rich,... arriving at an age of information junk" (cf. Branscomb, 1979).

Bibliographic databases. For the most part, bibliographic databases leave the user without effective means of filtering the literature. Consequently, users with whom we spoke report that they take advantage of general literature searches rarely, if at all. Collections of government reports and collections of items supplied by private for-profit services are regarded as especially problematic from a quality standpoint, because the entries have not been subjected to a recognized review process (cf. Corwin and Louis, 1982). A university researcher described one such literature search that yielded 1000 articles, only five of which turned out to be usable. As a representative from a large manufacturing corporation put it, "If you want goldfish, you fish in a goldfish pond; you don't fish in the ocean--you get too much of what you can't use."

Titles, abstracts, subject indexes, and key words are not precise enough to permit a selective look at the literature, especially in the social sciences. Most discussants thought that providing abstracts for all research with more complete documentation (especially of methodology) would help address the quality problem. In addition, they believed that improved indexing should be possible. Currently, according to its editor, *IEEE Transactions* is experimenting with both sorts of improvements.

Other individuals. If they have the manpower and budget resources, users prefer to have other individuals serve as quality filters. Most university-based users and several industrial representatives commented that graduate students work very well for this purpose, because they have substantive training, benefit from the literature search as a learning experience, and are relatively inexpensive. Policymakers and some industrial users cited the need for an experienced professional staff to sort and distill relevant literature; however, costs often make such staffing prohibitive (cf. McGowan and Loveless, 1981). Well-trained reference librarians were seen as vital sources of assistance in using bibliographic services to locate primary products, but were not viewed as helpful for making evaluative discriminations among them.

Numeric databases. Formally validated data programs such as those for materials properties data or the National Library of Medicine's Toxicology Information Program are expensive and concentrated in areas where the need for precise numerical values predominate. In other areas, the quality of available numeric data is generally agreed to be dubious (Hawkins, 1980; Adam, 1975). Further, much improved documentation is needed to make machine-readable data more generally useful, along with systematic notation about variable definitions, missing values, methodological problems, and so on (see Robbin, 1981 and David, 1980).

Sources we reviewed essentially concurred with the conclusion of a 1978 National Academy of Sciences finding that U.S. spending on data evaluation is disproportionately small in comparison with amounts spent on generating it (cf. Branscomb, 1983). Nationwide, support for evaluation and dissemination of numeric data has been estimated at between six and ten million dollars a year (NAS/NRC Committee on Data Needs, Roth S/T Policy). In contrast, it is estimated that, in the chemical industry alone, between $6 billion and $10 billion could be saved each year in capital costs and operating costs if data needs were adequately met.

Although feasible, implementation of technology-intensive solutions to data quality problems face serious difficulties because of high start-up costs and operating fees as well as intersystem incompatibilities. Also, where implementation costs have been borne by the private sector, access has often been restricted. For example, even though the bulk of primary material collected by General Electric's EMPIS comes from open literature, access to the system GE developed is largely limited to its own staff (Westbrook, 1981). Industry-operated centers also restrict output to members. In some cases, they limit access to project results to firms supplying support for that project. Release to other members or to the public may be delayed, if forthcoming at all.

The present alternative: Informal contacts. At present, then, there are major obstacles to screening data for quality in a research area outside of one in which the user is professionally involved. As a result, we learned that most users rely as much as possible on collegial contacts. "Knowing who to call" was the solution to problems of locating high quality research literature employed most frequently by individuals we spoke with in academic, industrial and government agency settings. Peer networks are maintained both informally and formally (e.g., through organized meetings of special interest groups). Several users told us that, if members of their own contact network could not directly recommend a sought-for research product, they could usually refer the inquirer to another knowledgeable source. In addition, one industrial engineer remarked that, if there were any outstandingly good--or bad--work in his field of endeavor, the news would travel rapidly through collegial circles and he would be certain to hear of it. However, through informal contacts, individuals can learn only what others in their network happen to know--and all individuals are faced with too large a quantity of information to screen. Clearly, other more systematic means of evaluation are desirable.

USER-RESPONSIVENESS

Status and Achievements

Few formal information transfer systems allow easy access and specification of search and delivery procedures by the user. Despite the ubiquitous availability of information and the presence of online abstracting and indexing, most online searchers are information intermediaries like librarians. Nevertheless, with the development of more flexible software, online services are beginning to design systems to enable the user to obtain data more readily on their own. So far, these efforts are rudimentary and not widespread.

Mechanisms to create or enhance informal information channels have had varying success. Databases identifying researchers engaged in ongoing research, such as the Smithsonian Science Information Exchange, have received little usage. The SSIE was recently discontinued, and the Federal Research in Progress database created by NTIS as a successor has sharply curtailed descriptions and coverage. In contrast, ARPANET, CSNET, and other interactive messaging systems have proved more successful within their clientele, probably because they are patterned more closely after self-generated collegial exchange. Programs employing link agents to unite users with information sources have had varied support and varied success. The NASA technology transfer programs have produced some successes, although their regional information analysis centers have declined in recent years. On the other hand, university-industry research programs, designed to put knowledge producers and users into direct contact with one another, establish more participatory information transfer and have been expanded.

Participants in our discussions indicated that federal information services often failed to aggressively market their wares to the user community. However, measuring the success of formal information channels is difficult. Many government databases rely on commercial online services, for example, to provide computerized access. Information on customer usage is thus proprietary. One survey did show that 69 percent of defense industry engineers surveyed had either never heard of the Department of Defense's information analysis centers or did

not know what they did (Corridore, 1976). Seminars and workshops may be used by agencies to promote awareness of key technologies and new tools. Some programs to improve curricula in higher education perform a similar function. Several private- and public-sector information managers indicated that major changes in scientific and engineering curricula should be made to train new generations to use the new information access tools.

Users may attempt to become more familiar with online systems on their own if they believe the information they acquire by that means is worth the trouble it takes. For example, in recent years, some scientific journals have been made available as machine-readable data files. Many of them are now beginning to go online with commercial services such as BRS. Full-text searching offers access to articles at the level of specific information needs, although hampered substantially by the current omission of graphs, figures, and other non-alphanumeric information. Advanced online information services, such as CAS Online or Questel/DARC, are beginning to offer graphic retrieval capabilities for users with appropriate terminals. The chemical information systems lead the way in this area, but graphic full-text systems for physics, electronics, and patents are in the planning stages. An account of the development of federal policies and practices aimed at making R&D information products more user-responsive is presented in Appendix B.

Problems

Like quality assurance, user-responsiveness issues are related to information availability. Rapid expansion of the scientific and technical information base has dramatically increased the difficulty of locating problem-relevant research results and translating them into improved products or processes. As Bozeman and Kim (1981) point out, "It cannot be assumed that scientific knowledge will flow into industry at a rate commensurate with its utility" (cf. Bikson et al., 1981). Key obstacles to promoting user-responsiveness include interdisciplinary barriers, communications gaps between information producers and users, and lack of interactive user guidance in the information transfer process. Consequently, contact networks and interpersonal interactions become the user's major tools for acquiring research knowledge.

Interdisciplinary barriers. Putting research knowledge to use frequently requires transferring it to a context quite different from its context of origin. However, scientific and technical information is organized along traditional disciplinary lines, as are subject matter indexes, abstracts, and key words. Thus, users find focused multidisciplinary retrieval extremely difficult (Adam, 1975; Allen, 1969). Moreover, this problem has grown increasingly important as disciplinary boundaries have become blurred (Fjalestad, 1983; Tornatzky et al., 1983). Our discussions produced several examples of literature searches that became excessively cumbersome and unmanageable because of the need for multidisciplinary access. These searches included work on manpower projections, international industrial competition, and technology transfer itself. Difficulties in obtaining information are exacerbated when different methodologies as well as different constructs are united in one research project, as happens in hybrid areas such as biotechnology, environmental impact assessment, and the like (Lide, 1980; Bozeman and Blankenship, 1979). In short, formal information transfer procedures are not responsive to users' needs when the user's environment is not well aligned with standard disciplinary taxonomies.

Formal dissemination mechanisms are particularly ineffective for transferring results from research to application, since they do not provide for the organization of information according to problem relevance. Rather, as we have noted, secondary sources yield pointers to the scientific subject matter of research and give no indication of its potential instrumental value. As one engineering researcher put it: "Science is universal, but technology is local" (cf. Tornatzky et al., 1983; Bikson, 1980). Blurring of the distinction between "basic" and "applied" research has not improved the problem-relevance of formal dissemination mechanisms (Fjalestad, 1983; National Academy of Engineering, 1981).

Two sorts of targeting efforts have been undertaken to increase the likelihood that research results will reach users who need and will apply them. One is to identify potential users of the results of a research project and distribute its information products directly and promptly to them (e.g., Glaser, 1980; Rich, 1981). This approach has,

with some exceptions, not been notably successful. "You can't expect solutions to go looking inside organizations for problems," commented a discussant. However, others believed that a more careful effort to target opinion leaders in potential user clienteles might help, following the strategy of mass media in segmenting the market and stimulating product demand accordingly (cf. Wright, 1969).

The second type of targeting effort has been to define areas of national need and fund problem-oriented research in those domains, on the assumption that the results will be readily applied when available (e.g., NSF's former RANN program). This approach too has had only mixed success. Those with whom we spoke generally believed that overmanagement of research from an applied perspective would impair scientific advance; in addition, they believed that users themselves were much better able to define priorities for applied research than were government agencies (cf. National Academy of Engineering, 1981).

In sum, formal one-way "supply-side" transfer procedures do not seem to be responsive to the user context. Rather, these efforts appear to start with an information system into which they later try to retrofit users' requirements (Adam, 1975). Indeed, many discussants believed that dissemination activities were afterthoughts, undertaken without serious commitment by federal agencies whose primary concerns were with research production and not with knowledge transfer. Further, 70 percent of federally supported R&D is carried out in private or local public institutions. The effective coupling of these undertakings with specific user needs would, under any circumstances, require considerable oversight and management. These qualities are likely to be difficult to secure, judging from the lack of coordination of science information policy across government agencies (Branscomb, 1980; Bozeman and Kim, 1981).

The producer-user gap. While dissemination policies and practices have chiefly employed one-way source-to-user transmission, the consensus of findings from empirical research is that interactive, two-way communications are required for effective information transfer (cf. Tornatzky et al., 1983; Beyer and Trice, 1982; Gerstenfeld and Berger, 1980). That is, much of what has been learned about effective information transfer has not been incorporated into federally supported

dissemination activities. An often-cited impediment to the development of a two-way exchange are the well-established "cultural differences" between information producers and potential users. These groups have different values, norms, assumptions, focal interests, and communication networks; they belong to nonoverlapping collegial circles (Beyer and Trice, 1982; Glaser, 1981; Bikson, 1980). Nevertheless, some dissemination procedures have supported interactive exchange using persons as knowledge transfer media.

One set of practices entails putting active intermediaries into the knowledge transfer process. In some instances, the intermediaries represent the information supply side; affiliated with funding agencies or research-producing institutions, these individuals are expected to serve as "knowledge brokers" or "linking agents" (e.g., McGowan and Loveless, 1981; Goldhor and Lund, 1980). Intermediaries affiliated with user organizations, in contrast, act as "technological entrepreneurs" or "gatekeepers" (e.g., Bozeman and Cole, 1982; National Academy of Engineering, 1981; Allen, 1977). Individuals in these roles filter information for relevance, translate it into usable form, and give specific problem-oriented feedback. Identification of appropriate individuals and support of their functions has been attempted on a limited basis (e.g., Glaser, 1978), and most individuals we talked with thought such practices should be more systematically encouraged. Empirical findings on the effectiveness of these intermediary roles are, however, sparse and inconclusive (Beyer and Trice, 1982; Rich, 1981). Their impact is likely to be strongly conditional on specific institutional contexts, and they may be costly to maintain.

A second set of practices involves putting research producers and users into more direct contact with each other. This approach seems more promising because it makes information exchange a function of the regular activities of both producer and user groups and because, once initiated, it does not have to depend on special funding for its maintenance. A long-recognized and highly successful person-to-person transfer of research knowledge occurs when graduate students obtain employment in applied science and technology settings. The main problem with support of graduate education as a transfer mechanism is that it takes too long (cf. NASA, 1966). For more timely dissemination, other

types of manpower exchange between information producer and user communities are valuable. Most of our discussants thought that one-shot site visits and joint conference attendance were desirable but less productive than the longer-term interactions that result from employee exchange programs or from consultative arrangements, although the former may promote the latter (cf. Beyer and Trice, 1982; Arthur D. Little, 1979; Mesthene, 1972).

Other major avenues for direct interaction between information producers and users are collaborative research projects and more comprehensive cooperative research centers (Eveland et al., 1982; Tornatzky et al., 1982; National Science Board, 1982; Baer, 1980). The cultural barriers cited above tend to present initial obstacles to the formation of such alliances. For example, a vice-president of a product development laboratory told us that "academics have no idea what might be useful to industry"; their orientation is "too abstract," their timeframe is "unrealistic," and their attitude is "contrary to transfer" and "holier than thou" toward applied scientists. On the other hand, a university engineering professor remarked that industry representatives have a "very narrow focus"; they are "so practical and so development-oriented" that they "lack the perspective for looking at the long-term significance of more general research." In addition, participation of private for-profit firms with public or not-for-profit institutions in joint scientific and technical activities raises questions about the protection of proprietary data as well as the patenting and licensing of resultant products.

The many successful examples of ongoing collaborative research indicate that such barriers can be overcome, and representatives of industries and universities concurred in urging the strengthening of these efforts. Advantages are, first, that they give rise to "generic" research that is intermediate between basic science and product-specific development, promoting basic-to-applied transfer. Second, continued interaction permits information to be integrated and focused in response to user needs, facilitating timely application. Third, these efforts give more leverage to federal research funds by stimulating industrial support (Slaughter 1981). Finally, they have done much to alleviate the industry-university culture gap; "a significant improvement in these relationships appears to be underway" (Fowler, 1984).

Lack of user control. As we have seen, a shift from supply-side emphases to more interactive models of dissemination is required when the policy objective moves from information availability to information usability. The logical extension of this trend is the development of policies that enable users themselves to have greater control over knowledge transfer processes for purposes of achieving product or process improvements. Since the classic study by Coch and French (1948), it has been acknowledged that participation in an information process significantly increases the likelihood that participants will act on the results. Three types of approaches to shifting the knowledge transfer initiative to the user side have been attempted:

- Limited, experimental attempts have been made to adapt information technology so that users themselves can command information resources. Briefly reviewed in Wigington (1982), these approaches include software for permitting users to define information searches around their own needs and to retrieve and manipulate data. They also include access to electronic contact networks that facilitate information resource sharing among users. According to Bozeman and Blankenship (1979), automated systems must be user-guided or they will repeat all the known problems of other dissemination procedures. Most of our discussants believed they could be taking better advantage of advanced information technology than they were at present (cf. Fjalestad, 1983; Engelbart, 1975; Adam, 1975; NASA, 1966).
- Another approach is to encourage interaction within user communities (e.g., Fusfeld, 1979; Brigham, 1975). Such exchange has been shown to lead to innovation and to application (Bozeman and Bozeman, 1981; Gerstenfeld and Berger, 1980). According to Tornatzky et al. (1983), recognition of networked or "peer-matched" models of scientific communication as alternatives to the center-periphery or clearinghouse models should help promote direct interorganizational interaction. However, there are serious institutional barriers to resource

sharing and research collaboration among industrial users. Said one representative of a collaborative program, "A major impediment is that all industries have to compete," which means they have to "hoard results" instead of cooperate. According to Rich (1981), institutional boundaries and competitiveness also impair resource sharing among public agency users.

- A third approach is to provide tax incentives and regulatory reforms to strengthen private-sector participation in R&D and promote utilization. For example, the Economic Recovery Act of 1981 awards tax credits to for-profit firms that support basic research. Similarly, recent changes in patent regulations permit some exclusive license rights to firms that have developed innovative products on the basis of federally funded research results. The impact of these policies on knowledge transfer has not yet been systematically evaluated. However, discussants believed that counter-incentives (such as antitrust laws and unrecoverable innovation costs) still outweigh positive factors (cf. Pavitt, 1979; Mesthene, 1972).

Lide (1981) and others believe that effective strategies for matching information resources to information needs deserve immediate attention. Such strategies take into account the fact that effective user-oriented transfer is not just an information-screening issue but is also a behavioral, institutional, and economic issue. Without these strategies, it is likely that "information will continue to be collected and absorbed at an exponential rate while the ability to understand and manage it will diminish" (McGowan and Loveless, 1981).

III. POLICY OPTIONS AND THEIR MERITS

Review of past and present dissemination policies and practices clearly establishes a need for more interactive, user-guided information transfer. Passive access to voluminous stores of textual and numeric data does little to promote timely, selective retrieval and application of high-quality R&D results. Therefore, in the options we describe for improving information transfer, the emphasis is on increasing the user-responsiveness and selectivity of existing formal dissemination systems and coupling them more closely with informal systems.

We organize our discussion of policy options into three groups--technology-intensive options, supply-side options, and user-focused options. Of course, the division is somewhat arbitrary, and specific alternatives are interrelated in that the merits of some will depend on whether others are adopted. In each category, we give greatest attention to those we judge to be the most promising alternatives. Further, we emphasize the needs of nonacademic users of information, because our evaluation indicates they are at greatest disadvantage under current dissemination procedures.

TECHNOLOGY-INTENSIVE OPTIONS

By technology-intensive options, we mean policy alternatives that take advantage of the special properties of computer and communications technology for the transfer of scientific and technical information. Technology-intensive options serve two major objectives: putting users into more direct contact with stored information, and putting users into more direct contact with other parties to the scientific exchange.

The most important features of electronic media for this purpose are the flexibility, manipulability, timeliness, and interactivity that they can contribute to information transfer. Although the publications and information services industries rely increasingly on electronic technology for internal operations, we focus here on its potential for enhancing the participation of end users in the dissemination process.

Interactive Networks. Policies could be designed to promote and support the development of computer-based connected networks that will allow interaction among participants in the scientific communication process. For this purpose, the federal government might fund exploratory efforts to determine how electronic technology can best be deployed to extend the known benefits of informal interaction. These experimental efforts could take a variety of directions, as we suggest below. We believe that the seeds of substantive advance may well be found in this arena.

- Electronic message exchange systems can potentially generate *ad hoc*, self-configuring groups. Interest groups of this type can carry out functions of informal systems such as alerting members to research projects initiated, broadcasting information needs, exchanging quality judgments, passing on significant new findings, conferring about applications, and the like (cf. Cronin, 1982). Current ARPANET groups function successfully in this model.
- Communication networks can also be used for more extended information resource sharing, such as exchanging primary data or preprints, forwarding documents or references to them, and so on. Head notes from other network members would help users filter and select from available online materials. In this fashion, users might develop their own dynamically updated and customized information resources (cf. Engelbart, 1975).
- A community of users participating in such a network over time would generate valuable by-products. For example, user-profile-based mechanisms for helping users locate relevant information products can be made self-improving; or, shared evaluations of information products can be used to derive parameter weightings helpful in qualitative filtering of information products.
- Project-based networks could be initiated to put representative potential users in contact with researchers throughout the course of a project. Feedback to knowledge producers would help insure the usability of the results, while users would have timely access to project findings.

- Finally, such networks could be interconnected to yield a multiplicity of coupled systems that would constitute a national decentralized information sharing capability (NASA, 1966). That is, while allowing for the formation of specific groups, computer-based communication systems also provide for the possibility of one "electronic college."

For exploratory research to test the effectiveness of policy options of the sort described above, implementation is the primary consideration. A real opportunity for rapid advancement in information dissemination and utilization may lie in stimulating and supporting the use of interactive networks. Many of our discussants suggested innovative R&D efforts in this area. We believe it would be productive to explore the feasibility, perhaps on a pilot project basis, of a dissemination policy option which would combine the following properties:

- Establishing a National Science Network (NSN). This network could use the identical technology to ARPANET and thus capitalize on the 15 years or so of research which underlies its success. Many of the information dissemination, access, and sharing techniques already well established could be applied immediately to the U.S. scientific community at large.
- Mandating access to the NSN, perhaps as a part of conducting NSF-sponsored research. NSF could use the network for proposal submission, award announcement, collection of results, and reviews. The public at large could be granted access to the network on a *pay as you go* basis.
- Encouraging information entrepreneurs to use the network and data bases connected thereto to provide worthwhile and profitable information dissemination services.

These kinds of policy initiatives take advantage of electronic technology to establish direct, timely, and interactive contact among participants in the R&D dissemination process. They couple the power of

computer systems and human communications processes to provide members of the scientific community--information users and producers--with access to each other. Ongoing self-generated exchange would be expected to promote knowledge transfer and enhance innovative utilization. Because these options make use of extant technology and known procedures, they avoid heavy technical development costs. Further, once shown to be of value, they are readily generalized. Because they represent a marked departure from present practice, such initiatives are exploratory and not without risk. On the other hand, in contrast with marginal improvements in conventional approaches, they hold the potential for significant new benefits. We believe the technology infrastructure for such activities is fairly well developed. Most researchers and many government and industry users have access to computers and communications systems. However, small businesses, local government agencies, and other users who lack access to computer resources might require special assistance.

User-guided search and retrieval. Policies could be designed to support the exploration and development of more flexible and powerful user-guided methods for accessing and retrieving highly structured textual and numeric databases. For this purpose, the federal government might fund adaptations of high-level languages and knowledge-based systems for intelligent location and use of scientific and technical information.

- A mechanism could be provided to enable users to express requests, define ways of examining a database, browse, make heuristic searches, carry out inferences, and the like. Many of the participants in our discussions regard supporting these capabilities for users as far more effective than trying to specify in advance fixed sets of search criteria or to explain to someone else what kinds of information might be desired.
- A knowledge base could be constructed to encompass a set of bibliographic or numeric databases relevant to the interests of a user group(s). The knowledge base can serve as an intelligent intermediary between the end user and stored information, "knowing" which databases should be searched in

response to a given request and which search procedures might be employed. Several individuals recommended applying such artificial intelligence approaches to the problem of selective, user-responsive information retrieval.

- Systems can be developed to permit users to manipulate the data retrieved in a search. Whether it is textual or numeric, the information output resulting from selective user-guided searches could be made available for subsequent processing by users and direct incorporation into their work.
- For numeric databases, coupling of search and retrieval processes with manipulation and analysis procedures would allow for comparative examination and evaluation of stored information either by an information service provider or an end user. Data cleaning programs have been developed over some databases for this purpose; they could be made more generally available.

Efforts to provide user-guided search and retrieval mechanisms and intelligent interfaces to multiple databases would require the funding of research and development projects. These capabilities are beyond the current state of the art, although it may be possible to adapt existing technology to these purposes. For example, a powerful and flexible language would have to be adapted to permit nontechnical users to query a database and guide a search. Textual or numeric data would have to be consistently structured and formatted for such treatment, ideally linked to a knowledge base that could provide the mechanism for intelligent computer-aided searching. However, projects that apply advances in artificial intelligence and expert systems research to problems of knowledge transfer were seen by our discussants as having significant long-term potential for improving the integration, evaluation, and utilization of growing stores of scientific and technical information.

Other Options. Other options, suggested both in the literature and in discussions, for taking better advantage of computer and communications technology in the dissemination process primarily concerned electronic publication. That is, many believe that the federal government could take steps now to encourage and support the

electronic storage, distribution, and consumption of primary research and development products as well as secondary products such as texts, reviews, and handbooks. Although electronically captured information can readily be printed, going from print copy to electronic copy may be costly and time-consuming, and can introduce new errors. Consequently, insofar as possible, it would be desirable to have research reports and other deliverables submitted in electronically accessible form. In particular, any products that require regular updating (e.g., handbooks and compilations) could be maintained online. Equally important, information products that potentially bear on the same problem--whether textual or numeric--could be retrievable through an integrated access mechanism whether they are in the same or different databases.

As a corollary, the federal government could consider exploring, designing, and promulgating standards for consistency and compatibility in computer and communications systems used to disseminate scientific and technical information--along with other major actors including representatives of private industry and international scientific bodies. Standardization might be pursued broadly in relation to all aspects of information technology that affect connectivity; that is, standardization efforts need to consider not only the components directly involved (e.g., storage and retrieval mechanisms) but also the body of lower level information technology standards (e.g., communication protocols) on which they necessarily rest. In consequence, any move toward standardization would confront a host of unresolved technical issues. However, we emphasize that the unexplored value of electronic technology does not lie merely in increasing the efficiency of the formal publication and dissemination system as it now exists, but rather in dynamically uniting that system with its users.

SUPPLY-SIDE OPTIONS

We describe below some policy alternatives that attempt to improve dissemination processes from the information supply side; they could make use of but do not require the more technology-intensive options discussed above.

Improving information organization. Our evaluation of current dissemination procedures established the need to improve the access structure for stored information. Indexes and abstracts do not enable users to make highly selective searches, particularly when their information needs are multidisciplinary or applied. The federal government could support exploratory efforts to improve the filtering capability of these tools. Recommendations we encountered to increase search selectivity included the following:

- Abstracts themselves could provide more complete research information, especially about methodology employed, availability of data, and expected areas of application. Improving the contents of abstracts on a nonretroactive basis would be less difficult or costly to implement. Changes in key words or addition of new information, such as data flags, to extant databases would be much more expensive and time-consuming.
- Information can be organized according to "naturally" occurring clusters. Making use of citation indexes and current bibliometric techniques (see Appendix B), cocitations could be used to derive an interrelated collection of scientific and technical information *ad hoc*--in response to individual user requests--rather than by specifying keywords from a predetermined list. This type of user-oriented organization procedure could reduce the quantity of information retrieved in a search while improving its relevance and quality, as experimental studies have shown (Price, 1974).
- Abstracts and key words could be organized "conceptually," with terms from different disciplines serving as pointers to common knowledge domains. This type of organizational effort would require creating an interface capable of reconciling key words for similar subject matters in different databases as well as joining associated concepts from different disciplines in the same or different databases. Besides helping to integrate diverse literatures, this option would also help to eliminate redundancy in searches (cf. Adam, 1975).

The last policy option would require developmental research, while the others could be implemented with extant technology. All three aim at making desired information easier to find. Their effect on the dissemination process would depend on whether the increased discriminability they provide motivates users to take better advantage of passive-access avenues to growing information resources

Data quality. Quality assurance involves two sorts of issues: (1) Can users trust numeric data collected in research projects? (2) Can users trust the conclusions drawn from the research? The options below address the former question. Our examination of current policies and practices led us to conclude that secondary uses of numeric data could be significantly increased if data quality were assured. Moreover, the importance of secondary data use increases as funds for primary data collection become scarce. Recommendations in this area include the following:

- In a number of research fields where property measurements or observational/environmental data are collected, standards for evaluation exist (e.g., CODATA). Many sources recommend the systematic allocation of funds for evaluation of resulting data of this type when grants or contracts are awarded. It has been estimated that evaluation would require 5 percent or less of the cost of data generation (National Academy of Sciences, 1978). The federal government might investigate alternative mechanisms for accomplishing data evaluation:
    - Information analysis centers could expand the scope of their data evaluation activities.
    - Evaluation efforts could be flexibly staffed by experts on a consultative basis; after termination of a primary research project, results could be appraised and integrated with existing critically evaluated data sources.
    - Given integrated online datasets and access to data-cleaning tools, evaluation could be carried out by users on an as-needed basis.

- Statistical data (on public health, economics, demographics and the like) still require the development and promulgation of criteria for quality evaluation. Agencies that fund collection of statistical data could collaborate in defining evaluation criteria. Eventually, statistical data evaluation could be handled in the same way as property measurement and observational/environmental data.
- Finally, several sources recommended exploring procedures to integrate textual information with numeric databases for annotating specific problems (e.g., measurement difficulties, methodological difficulties, problematic codes and the like). Many sources (e.g., Robbin, 1981; David, 1980) mentioned that lack of such annotations either rendered otherwise adequate files unusable or else induced major delays. Development research would be required to act on this option

Integration and evaluation of numeric data, however undertaken, involves combining information from many sources and thus entails high costs, in part because of inconsistent formats, file structures, and the like. Consequently, such tasks would be aided by standardization (see above). To reduce initial costs, data quality assurance could be supported first in areas where government and industry have identified needs for critically evaluated sources.

Active information intermediaries. Dissemination literature indicates that information is best transferred by a human agent capable of entering into a dialog with users. This sort of exchange is particularly important when the information is for an applied problem. Further, the transfer agent needs to be substantively knowledgeable in order to respond to the questions raised by potential users. There are numerous models for building this sort of function into the activities of knowledge producers (e.g. Glaser, 1978). Several sources have recommended that, near their completion, research projects be evaluated for their potential application to either government or industry. Agencies could provide low levels of funding (or explore other incentives) to allow representatives of promising projects to act as

knowledge brokers after the research period. In this capacity, they could provide user-relevant information and technical assistance.

The cost of limited support for information intermediaries is difficult to estimate but is likely to be a major factor in decisions about their use. In some instances, public research institutions have been willing to bear the expense as part of their community relations activities. In other cases, these activities are seen as laying the groundwork either for further collaborative research or for consultative user-compensated arrangements.

Other options. Other supply-side options we reviewed relate mainly to coordinating information supply. For example, some have mentioned the possibility of preparing and maintaining a single, complete, continuously updated directory of scientific and technical information resources (in contrast to the many partial listings that now exist). Such a register could tell how to find out about information services and products; it could list evaluated data sources and provide a guide to technology transfer efforts (cf. National Academy of Engineering, 1981). The need for agency-wide coordination has also been remarked; most individuals we talked with have had frustrating and unsuccessful experiences trying to learn about the existence, location, or content of agency reports. These problems might be alleviated if, within each R&D funding agency, an office were established with responsibility and authority for agency-wide tracking and management of information products. Valuable insights about the feasibility of any of the above options might be derived from a study of what real incentives R&D funding agencies have to devise and carry out effective dissemination programs.

USER-FOCUSED OPTIONS

Not much attention has been paid to policy options that empower users to play a stronger role in the transfer of scientific and technical information. However, our review suggests that user-focused alternatives are quite promising. But because users comprise such heterogeneous groups and because there is no national policy history on which to build in this area, it is difficult to provide confident recommendations. In fact, some discussion participants suggested the

best first step might be to convene policy brainstorming sessions with groups of potential users to elicit innovative and promising options. We believe that idea has considerable merit, given the quality of the appraisals and recommendations we elicited in the small number of discussions we conducted during this project. In the meantime, we offer the following options. They could be enhanced by, but do not require, implementation of technology-intensive options.

Skill building. Discussion comments indicated that the majority of potential information users--even those in large organizations--either are unaware of information resources in their field or do not know how to use them. In particular, it was suggested that, if users are to have a more active role in information search and retrieval, it is important that they understand types of information products and services, information systems logic and characteristics, and information resource management (cf. Beyer and Trice, 1982; McGowan and Loveless, 1981; Bearman, 1981; National Academy of Engineering, 1981; Garfield, 1979). We refer here to how information is organized and accessed in general, not to protocols, keywords or other system-specific properties.

- The federal government might support institutions of higher education in developing curricula related to effective use of information systems by people other than information professionals. Future users would then be able to take better advantage of advanced information tools (Surprenant, 1982). At the same time, it has been suggested that short courses or workshops be developed in this area for current users employed in industry and government.
- Second, curricula could be developed to fill an identified manpower need for individuals who are substantively knowledgeable in a field and who have expertise in computer-based information systems. This new breed of professionals would be capable of matching users to information resources by virtue of being (a) conversant with the scientific and technical domain, so as to understand users' information needs; and (b) conversant with the computerized environment, so as to translate those needs into information actions.

- Third, it was suggested by a number of discussants that special assistance in using information resources be made available to small businesses and local government agencies. Institutions without slack resources may be unable to take advantage of nonproprietary scientific and technical information. Ways of supporting access to computerized information services and products could be explored. Further, agency-based "consultants" could be made available to help users carry out computer-based search and retrieval.

Stimulating and supporting the development of courses related to information systems use would fall within existing programs for funding higher education. Once in place, the courses could be maintained by the institutions offering them. On the other hand, the last option raises a number of issues about the fair allocation of costs. In view of those difficulties, we give it a lower priority.

User-driven dissemination. Empirical research consistently finds that when information transfer actively engages the users, it is likely be more successful (e.g., Tornatzky et al., 1983; Bikson, 1980). As Bozeman and Blankenship (1979) note, it is more effective to build information systems around user preferences than to try to build user support for formal systems that do not reflect their preferences. Several policy options have a user-driven orientation:

- A number of research projects have been conducted (e.g., Glaser, 1980) that relied heavily on feedback from advisory committees composed of potential users. As a result, research products reflected user needs and were more readily, promptly, and widely applied. It has been suggested that, in applications for grants or contracts, researchers be required to identify potential user groups. A condition of awards could be the naming of a project advisory board comprising representative stakeholders whose function would be to guide instrumentally relevant aspects of the research, review final products, and assist in further dissemination.

- Second, it has been recommended (cf. Bozeman and Cole, 1982) that efforts be made to identify or encourage "gatekeepers" or "technological entrepreneurs" within user settings. These are individuals who acquire cutting-edge scientific and technical information more rapidly than their peers and translate and diffuse it throughout their organizations. As Bozeman and Cole (1982) point out, identifying such persons in advance is difficult; however, methods for rewarding them should be much less difficult to devise and could be explored.
- Third, it has been recommended that the development of informal collegial interactions within and between user communities be encouraged. Boundary-spanning communication across organizations has consistently led to knowledge transfer and innovation (e.g., Gerstenfeld and Beyer, 1980). However, informal linkages are typically less well developed in nonacademic communities, even though nonacademic users are likely to make more use of verbally communicated information than their academic counterparts. Ways of facilitating the development of user contact networks could be explored.

The user-driven dissemination strategies we have discussed are difficult to appraise because very little is known about how user communities are organized to acquire and distribute information. This reflects the fact that both research and policy have emphasized the information supply perspective. Thus, while there are examples of successes in the three policy option areas cited, it is unclear what would be required to implement them systematically. On the other hand, it seems evident that implementing user-driven policies does not require federal agencies to anticipate and select key problem areas or key industries as dissemination targets; they need instead to increase user involvement in setting research agendas and knowledge transfer priorities and procedures.

Collaborative research. We have learned in this review that the nature of the research and the participants in the research process have a great deal to do with subsequent information transfer and utilization.

Long term collaborative research efforts that address a multiplicity of problem-related issues are likely to yield a high-volume transfer of findings.

- Several individuals with whom we spoke during this study endorsed the option of increased funding for "generic" research intermediate between basic science and product development. Process technologies are perhaps the clearest example. Such investigations yield findings that have immediate application value. However, the building of research teams and coherent bodies of results should be viewed as a long-term effort. Short-term narrowly-focused one-shot projects were regarded as less likely to generate results of reliable value.
- Discussants as well as literature sources concurred in urging continuation and expansion of support for collaborative industry/university research. Current practices have done much to break down barriers between these communities (Fowler, 1984). In addition, more dual-function research and production efforts could be undertaken (modeled, for example, after the submicron structure facility at Cornell, which is both a fabrication resource and a research center for fabrication technologies). Collaborative research does much to leverage scarce agency funds by coupling them with industrial support. At the same time, joint undertakings provide potential users with opportunities for input and interaction throughout the research process while greatly increasing the utility of the results to participants.
- Finally, federal agencies could explore ways of fostering direct resource sharing and research cooperation within industry. It is likely that industrially-based research centers with users participating in the project development process from the outset would generate highly useful results. It is not apparent that such consortia gain by being entirely university based.

Developing collaborative programs of generic research appears to be one of the best ways of insuring the regular transfer of results to contexts of application. Further, such programs receive substantial industrial support. The need for government involvement in the process seems to be two-fold. First, while early participation in an R&D process usually gives a firm a competitive edge in product development and marketing, it is well established that these advantages are not sufficient to recover full costs of the research (e.g., Pavitt, 1979). Rather, the social benefits from industrial innovation outrun capturable rates of return. (One industrial representative commented that it is ideal to become the second company producing an innovative product.) Second, institutional mechanisms do not exist for facilitating industrial research consortia. Rather, current practices foster competition and, as one industrial engineer put it, "hoarding rather than sharing" of results. Thus approaches need to be defined for supporting industries to collaborate in the conduct of long-term generic research from which all could benefit, but which few could justify individually.

THE BROADER CONTEXT FOR POLICY OPTIONS

At many points, the preceding discussion of policy alternatives raises issues that go beyond information dissemination procedures themselves and involve the broader context in which such policies are embedded. Information transfer policies cannot be formulated apart from attention to the institutional, regulatory, and economic environment. Although an investigation of macroenvironmental issues bearing on information dissemination policies and practices would go well beyond the scope of the present study, we briefly describe the most recurrent concerns our study uncovered.

A national dissemination policy. Perhaps the most frequently raised broad concern is for a coordinated national information transfer policy. The United States does not have one (Bearman, 1981). Nor is there cabinet level representation for the independent science and technology agencies. While discussions and literature reviews yielded no clear consensus about specific policy vehicles, we found considerable support

for developing an integrated knowledge transfer system within the context of a national scientific and technical information dissemination policy.

Resolution of roles and rights. A second set of concerns involves sorting out roles and rights in the dissemination process for researchers, government agencies, scientific organizations, and private for-profit firms that provide "value-added" services in information distribution.

One problem is how the costs of computerized information searches should be covered. Our historical review (Appendix B) calls attention to the fact that if government agencies offer low-cost services, they are seen as competing with private industry; if they do not, users with limited budget resources may not be able to access nonproprietary scientific and technical information.

Copyright is another problem area. Taking advantage of online information resources by permitting users to access textual data, and by enabling them to retrieve and print (or otherwise manipulate) the portion they need, raises important questions about how rights of authors and publishers are to be protected. These kinds of questions need careful exploration in relation to dissemination policies and practices.

Tax and regulatory policies. Although tax incentives and regulatory changes do not automatically lead to changes in knowledge transfer, several recent events affecting that process were highlighted in discussions and related literature.

For instance, tax incentives for support of research and development were part of the Economic Recovery Act of 1981. While most sources believe more economic incentives for industrial support of research are desirable, the effects of the current tax initiative should be assessed.

Similarly, patent regulations were revised in 1981 to give industries that develop products more exclusive rights (even though they make use of nonproprietary information), on grounds that expansion in proprietary rights would encourage inventive activities. Many contend that further revision of patent law would be desirable. However, the effect of the 1981 change has yet to be evaluated.

Antitrust legislation is regarded as a potential barrier to industrial resource sharing and research collaboration. In particular, many discussants predicted the deregulation of the communications industry and its effect on Bell Laboratories would have a strong negative influence on industrially based resource sharing and generic research. This question likewise merits study.

Our discussion of the broader context of dissemination policies is not meant to be complete. Rather it is intended to provide specific examples of macroenvironmental issues that bear on the success of efforts to translate the results of federally funded research and development into process and product improvements.

IMPLICATIONS FOR NSF

The discussion of policy alternatives, we believe, suggests a number of directions open to NSF for improving the dissemination of scientific and technical information. Below we indicate what we see as the most promising first steps.

Research on advanced information technology. NSF's strongest influence appears to be exerted through the research it funds. To enable future dissemination programs to take full advantage of advanced information technology, NSF could solicit and support two sorts of research. Pilot or field-experimental projects might address the implementation of computer-mediated contact networks (project-based, user-based, and/or systems linking agencies, researchers and users). Experimental development projects could design user-guided querying tools, knowledge bases to support intelligent search of textual or numeric data, or interfaces capable of assisting users. The former efforts attempt to extend the known benefits of informal interaction in the scientific communication process, and the latter bring advances in artificial intelligence and expert systems research to bear on problems of effective knowledge transfer.

Extension of current research programs. According to discussions conducted for this study and to published results, NSF's support of collaborative industry/university research programs shows the utility of bringing knowledge producers and consumers into direct interaction.

These efforts could be continued, and alternative mechanisms for stimulating industrial cooperation in the conduct and support of intermediate research might be explored. A second area of effort that might be expanded is empirical research on information transfer and knowledge utilization. Much of what is known about information dissemination from an empirical and comparative standpoint comes from NSF-supported studies. Several discussion participants thought behavioral research of this type could be expanded.

Project requirements that improve transferability of results. Program solicitation announcements and proposal review criteria might be revised so that projects will have a greater likelihood of being funded if they include procedures for interaction with potential users of the resulting research. Above we have suggested several ways of achieving user participation: including an advisory committee of potential users who provide feedback and review at regular intervals throughout a project; including information broker activities for researchers at the conclusion of the work; and identifying information entrepreneurs within relevant user settings to whom results could be directly disseminated. These options are not exclusive; however, some will be more appropriate than others for any given project. Although any of these activities will increase project budgets, the utilization payoff may also be considerable.

Improvements in collected information. Information supply-side options could be reviewed to determine which, if any, could be implemented at small cost to improve the usefulness of extant scientific and technical information. For example, the NTIS database might provide an appropriate foundation for low-cost experimentation on co-citation-based report grouping as a way of helping users conduct more selective information searches. Or, NSF could undertake to improve future NTIS abstracts by including more information about research methodology and indicators of data availability. Further, the NTIS retrieval system might be used as a testbed for exploring the union of data retrieval with data manipulation algorithms. In any case, discussants suggested that internal NSF activities of this sort might become models and guides to other agencies.

Critical evaluations of numeric data deserve special attention because they are very costly to create and because, once established, evaluated data sources require regular updating and maintenance. Further, they could become de facto subsidies to large corporations, their primary users. On the other hand, they may have extremely high utility. Thus data evaluation could be undertaken where user groups can be identified who have major unmet needs for specific data sources appropriately filled by government activities (in some instances costs may be at least partially recoverable through user charges). Evaluated data sources integrate information from different databases supported by different agencies. While discussants agreed that NSF should encourage the strengthening of data evaluation, they were less clear about how to establish priorities and about appropriate NSF roles in these activities. Many believe that AI-based technology, yet to be developed, holds most promise for solving data evaluation problems.

Information system standards. Issues of standardization for computer and communications systems need to be addressed by an inter-agency body of some sort. While premature moves toward standardization can depress innovation and unduly constrain options, waiting too long can make the benefits of cost reductions in electronic technology more and more difficult to realize as printed matter proliferates. Because the development of viable standards is painstaking and will require a long time, it is generally agreed that such efforts should begin now. NSF might take the lead in initiating them, in order to bring potential technology-intensive options for information dissemination closer to reality.

Information policy leadership. There is widespread recognition that the United States needs coordinated national science information policies, of which dissemination policies are a part. However, discussions and literature reviews led to no determinate conclusions as to NSF's role in this area. Several believe NSF should serve as a national leader in information policymaking, acting not only to promote basic research but also to insure that excellence in science is adequately translated into product and process innovation. Others are skeptical about whether NSF could carry out such a broadened leadership

role. They do not want to see a weakening of NSF's support for basic research, and are unsure of whether this responsibility is consistent with the development of aggressive knowledge transfer policies. The question of how best to establish a high level base for scientific and technical knowledge transfer policy should be investigated and resolved.

APPENDIX A.
DIRECTIONS FOR FUTURE DISSEMINATION POLICY RESEARCH

In this report we have hardly scratched the surface of a large and enormously important area. Obviously, a good deal of study remains to be done to provide a detailed basis for improved federal information transfer policies. In this appendix, we discuss a framework for future research by drawing on the issues, problems, and options we have identified and discussed above.

We believe that continued study of information dissemination policy could productively pursue the following four topics, which we discuss in turn:

- Formal evaluation of current programs and options
- Technology assessment
- The regulatory-legal environment
- Comparative national policies and transborder information flow

FORMAL EVALUATION: ILLUSTRATIVE CRITERIA

Section II above informally evaluates major current policies and options for the future. A more structured and rigorous approach is needed in subsequent work. Especially important is analysis of costs and benefits as well as roles for the federal government vis-a-vis the private sector. A key problem is to specify the circumstances under which the government should pursue particular information transfer programs, rather than leaving these activities to the private market place. The proliferation of information technologies, systems and services has greatly complicated this question.

Addressing these and other considerations requires, as the first step, a well-defined set of evaluation criteria. We offer here a preliminary set of criteria to assist in this task (see Table 1.)

Table 1

SUMMARY OF CRITERIA FOR EVALUATING DISSEMINATION POLICIES AND PRACTICES

GENERAL CRITERIA

Cost, Benefits, and Equity
Institutional Feasibility
Technical Feasibility

SPECIFIC CRITERIA

ABILITY TO MAKE INFORMATION AVAILABLE	EVALUATIVE ABILITY	RESPONSIVENESS TO USER ENVIRONMENT
Comprehensiveness	Assurance of	Multidisciplinary Retrieval Capability
Assurance of Access	- Reliability	Problem-Relevance
Breadth of Access	- Validity	Amenability to User Direction
Timeliness of Access	- Documentation	Facilitation of Interaction
Continuity	Integrative Ability	
	Discriminative Ability	

General

Three criteria are so general that they enter all discussions of knowledge transfer policies and practices. They represent conditions that present and future programs should meet. At the same time, they raise special issues related to the use of advanced information technology to support Federal dissemination efforts.

Cost and equity are obviously important criteria for evaluating quality assurance and information transfer processes. Unfortunately, benefits are harder to measure than costs. The latter usually can be estimated tolerably well by adding up hardware and software costs, employee and other staff costs, operating expenses, and the like. But the benefits to users of scientific and technical information generated by government funding of basic research are more elusive. In principle, a good measure is the amount the users would be willing to pay, but determination of this amount itself poses problems. Moreover, it is hard to identify all possible beneficiaries. Some users may get their

information from other users, and identifying secondary users and estimating the value of the information to them as well pose additional complications.

One way to choose the most cost-effective options might be to compare the costs of competing processes whose benefits appear to be roughly the same and select the less expensive ones. In other cases, large differences in costs or benefits may make decisions easier. Generally, federal policies presuppose the social value of open scientific and technical literature and do not cost-justify it.

Equity, too, has been an important consideration. For example, federal programs assisting the private sector generally give special priority to small business and minority-owned enterprises. These groups may face special difficulties in fully utilizing scientific and technical information. The cost burden of hardware, software, and staff training may be high for small businesses that cannot exploit the scale economies available to larger entities. Federal policy may seek especially to assure that transfer processes be designed to meet the needs of small nonacademic organizations, since they seem to be least adequately served by traditional dissemination mechanisms. This emphasis could be embodied, for instance, in transfer processes that require only small up-front investments by users or modest staff skill requirements. On the other hand, for larger user organizations, such processes may be less effective than those that *do* require larger budget and manpower resources. A major policy issue, then, is how to enact effective and flexible options that will serve a range of user organizations.

Institutional Feasibility. Evaluations of current programs and future options must take into account the institutional difficulties of supporting or implementing them. These difficulties relate to appropriate roles for the federal government and the private sector, and the internal operation of the federal government.

The fundamental rationale for government involvement in dissemination is the "public goods" character of information. A "pure" public good is one whose use by one individual does not reduce the supply available to others. Once produced, it is available to everyone at no additional cost. (The clearest example is national defense.) The

private marketplace generally will produce less than the socially appropriate or "optimal" amount of a public good. Roughly speaking, the optimal level of information is that for which the value to the user of the last unit provided is equal to the additional cost of providing it. However, a uniform price to all users that is equal to the additional cost of serving each would not generate sufficient revenue to cover the producer's total cost. The producer could charge a price in excess of the additional cost to cover total cost, but fewer units of information would be sold at the higher price. Also, some users would be deprived of the information, even at a fair price (i.e., one that only supports cost recovery).

Information of value to a wide variety of users has a stronger public-goods character--and hence a stronger rationale for federal support--than does information tailored to the needs of a few. Whether or not information of private utility is produced depends on whether the value to any individual user at least equals the additional cost of producing it. In these situations, the private marketplace is generally relied upon to produce (or not to produce) the information. Thus, in examining the relationship of dissemination policy options, federal and private-sector roles, a major criterion is the extent of their public-goods characteristics.[1]

If there is a legitimate federal role in particular information transfer options, it is important also to assess feasibility in terms of the internal operation of the government. Options that can easily be implemented by individual agencies are more institutionally feasible than those that would require close coordination among agencies, new statutory authority, or creation of a wholly new agency. Similarly, the successes and failures of existing programs depend in part on the ease with which they fit into existing agency interests and mandates.

Technical feasibility. Any dissemination policy should be capable of implementation with currently available technology on an efficient

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[1] This distinction between types of information is similar to that between "basic" and "applied" research, where a clearer case for federal support of basic research can be made on grounds of its stronger public-goods characteristics. Of course, the analogy is weakened by the blurring of the basic-applied distinction and the need for "generic" research.

and effective basis. Normally this implies gradual or incremental evolutionary policy. However, we believe that government investment in information technology has emphasized capture and storage at the expense of more efficient access techniques (particularly in the realm of dissemination to nongovernment users of the data). Government investment in technology appropriate for information dissemination has been substantial. For example, the DARPA Network has been an ongoing government technology investment for over a decade. The results in the realm of information dissemination have been nothing short of spectacular. An entire research community (computer science) uses this network primarily for information transfer. This example suggests that much government technology investment has potential for broader realization of more efficient dissemination vehicles. Before any new inventions are applied to information transfer, an inventory of what already exists and the generation of appropriate plans for adaptation and broader implementation are in order.

Ability To Make Information Available

As we have indicated, existing policies and practices have been relatively successful in making scientific and technical information publicly available. In fact, observers of the information explosion have frequently commented that present utilization problems stem from having too much information available, rather than too little. However, because increasing use of electronic information systems in dissemination procedures unquestionably affects user access, policy options could be assessed in terms of the following availability-related evaluation criteria:

- **Comprehensiveness.** Federal dissemination policies should yield comprehensive coverage of advances in research and development within every discipline; no information should be lost.
- **Assurance of access.** The assurance of access may seem so inherent in the concept of information transfer as to be a trivial criterion. However, there is growing evidence that users experience considerable difficulty in actually locating

and acquiring material that is in principle "available." Information structures, search tools and dissemination media should promote confident retrieval.

- **Breadth of access.** Because potential consumers of scientific and technical information are diverse, dissemination efforts should reach multiple user populations.
- **Timeliness.** Dissemination policies should make new scientific and technical information available as it becomes known, or it will be of less value for stimulating performance and productivity improvements.
- **Continuity.** While the public- and private-sector organizations and services involved in knowledge transfer activities may change considerably, federal dissemination policies should provide for long-term continued availability of bodies of scientific and technical information.

Evaluative Ability

The issue of information quality assurance has attracted considerable attention in recent years. Providing quality controls and guidelines has been seen as a way of increasing users' ability to cope with the vast and growing array of scientific and technical information. The policy challenge is two-fold: to promote quality in primary information products (with special attention to the value of physicochemical reference data); and to provide users with more selective search tools, so that their ability to impose quality filters on available information (whether numeric or textual) is improved. The criteria described below, which place a premium on evaluating scientific and technical information, are suggested as ways of appraising the ability of policy alternatives to meet these aims.

Assurance of reliability, validity, and documentation. Information dissemination policies should encourage the adherence of all primary scientific and technical information products to the following objectives, which seem to define the quality dimension:

- *Reliability,* or the extent to which identical operations if repeated would produce identical data.
- *Validity,* or the viability of the logic underlying inferences and conclusions drawn from the data.
- *Documentation,* or the provision of clear descriptions of research design, variables, instruments, and procedures, along with explanations as to how results are identified, recorded and organized. As we have noted, standards for evaluation of reliability and validity differ in different research disciplines (e.g., physical properties vs. social data). However, full methodological documentation is a uniform requirement that will enable users to make better evaluations of research results in all domains.

Integrative ability. Federal dissemination policies should promote transfer procedures and services that can integrate or at least collate related studies, thus enabling the recognition of duplication, the comparison of results and conclusions from different studies, and the reconciliation of inconsistencies.

Discriminative ability. Federal dissemination policies should facilitate selective search and retrieval of research output within a given line of inquiry. While information access should not be constrained, users should be provided with some mechanism for determining the most relevant and important contributions to knowledge.

Responsiveness to User Environment

Federal information transfer policies could be assessed in terms of their ability to promote the aggressive matching of information delivery and information needs. This "user-responsiveness" dimension of information transfer (unlike the quality control dimension) does not have a long history of discussion in scientific literature. Nevertheless, recent empirical and analytic studies suggest several criteria related to user-orientation that may enhance information utility.

Multidisciplinary retrieval capability is the most frequently cited criterion in discussions of the usability of scientific and technical information. While knowledge needs that cross disciplinary boundaries have sometimes been thought to characterize only applied use, many current advances in basic research and development (e.g., in biotechnology, computer science) depend on interdisciplinary knowledge as well. This criterion does not imply that knowledge producers should not report results in the language of their research disciplines; however, information system structures and/or access mechanisms (e.g., keywords, indexes) should provide multiple routes to primary products.

Problem-relevance. To promote usability of scientific and technical information, dissemination policies also need to promote problem-focused retrieval. The great difficulty posed by this criterion is that the language, methods, assumptions, and values of the problem domain are likely to be quite different from those of relevant research and development domains. In addition, information structures and search tools are not designed to help users filter primary products for instrumental relevance.

Amenability to user direction. There is an even more basic concern to be faced in the effort to transfer problem-relevant information: Only users are well equipped to determine what is relevant to their problems. Moreover, prejudgments of relevance and other efforts to screen information run the risk of curtailing innovative or serendipitous information use. On the other hand, user involvement in the knowledge transfer process has consistently been associated with greater utilization. Therefore, federal dissemination policies should increase flexibility and advance user participation in information search and retrieval activities so that these processes become more user-guided.

Facilitation of interaction. Finally, one result that emerges strongly in research on knowledge transfer, regardless of domain, is that formal one-way channels are not, in themselves, sufficient to promote utilization. Rather, communicating information is much more effective when it occurs as an exchange, allowing for scientific dialog, iterative feedback, and refinement of implications. Consequently, federal dissemination policies should encourage the development of

interactive information environments that enable contact among users and between users and producers of scientific and technical knowledge.

TECHNOLOGY ASSESSMENT

We have concluded that much improvement in information transfer and quality assurance is possible with existing technology. Nevertheless, it is important to explore the potential impact of new technologies in a number of ways. First, they may provide greater flexibility in meeting specific needs. Today heavy reliance is placed on the relatively rigid subject-matter, key-word approach to search large data bases--an approach whose shortcomings we have emphasized. Expert systems, high level languages, and other outcomes from artificial intelligence research may make other approaches economically and technically feasible. For example, they might give rise to the design of more heuristic approaches, where users' iterative inquiries trigger more sophisticated, goal-oriented searches. Or, message networks may allow the development of self-configured groups that readily share and build on one another's information resources.

Second, the opportunities and problems posed by use of new technologies may both reduce and intensify institutional barriers. The degree to which federal agencies would have to cooperate to make best use of new technologies, the merits of a single agency having primary responsibility for interagency coordination of quality assurance and transfer policies, and the viability of today's decentralized system, could all be affected. Moreover, appropriate roles for the public and private sectors may change. We noted in our discussion of evaluation criteria that the more tailored is information to meet the needs of the individual user, the stronger is the rationale for its provision by the private sector. To the extent that new technology makes more feasible the tailoring of information to meet individual needs, the case is strengthened for having these new functions performed by the private sector. On the other hand, advanced information technology may permit users to tailor it themselves. Finally, the dependence of greater use of information technology for dissemination processes on the development of standards needs careful appraisal.

REGULATORY AND LEGAL ISSUES

Legal Liability

The issue of legal liability is particularly relevant to the task of quality assurance, whose importance we have emphasized throughout this report. Under what conditions should an organization that evaluates information for others be held legally liable if damages occur because the evaluated information is misleading, misused, or faulty? Westbrook and Rumble (1983) note that about 25 percent of lawsuits on new products allege engineering negligence. Because some of these cases arise from data problems, these authors urge that the issue of information liability be assessed; we agree. In particular, further study ought to be given to defining appropriate limits of liability and exploring the extent to which legal liability discourages organizations (for example, professional societies) from taking a more active role in quality assurance.

Copyright

Copyright issues have posed difficulties for many years with respect to protection of data bases and software, among other things. The National Academy of Engineering (1981) complained that, under existing 1976 copyright law, software developers

> have had to protect their investment by restricting its use through nondisclosure agreements or withholding it completely. Similarly, data base developers and services are reluctant to invest heavily in offering new information services in view of present ambiguities in the law.

The 1980 copyright law amendments adopted the recommendations of the National Commission on New Technological Uses of Copyrighted Works that "all computer programs, fixed in any method and performing any function, be included within copyright protection." Nevertheless, the problems of the sort expressed by the National Academy of Engineering persist because of difficulties of enforcement, ambiguities in the law, and new legal issues that arise because of continuing technological advances. As one example, the recent Betamax decision may expand the

legal interpretation of "fair use" for noncommercial copying, but the new boundaries of fair use will surely be the subject of continual litigation.

We have identified two areas in which further study is especially needed:

- Empirical examination of the degree to which both legal and illegal copying occurs. Beyond scattered anecdotal evidence, surprisingly little is known about the extent to which intellectual property is being copied and used. Thus, the true magnitude of the copyright problem itself is in doubt. Systematic empirical analysis is both feasible and would greatly assist the formulation of well-conceived future copyright policy.
- Analysis of new legislative initiatives that might be undertaken, based on economic efficiency and other criteria. Careful attention should be given to the extent to which development and use of intellectual property is less than socially optimal because of problems of defining and protecting property rights, and what can be done about it. Such considerations are especially important in view of the potential for retrieving and using parts of online primary or secondary research products.

Antitrust Considerations

Although the Justice Department has stated that it has never challenged a pure research venture without corollary restraints in trade, cooperation among private firms in R&D activities has been hampered in the past by fears of possible antitrust violations. However, joint R&D ventures are becoming increasingly popular, because of congressional and administration encouragement and proposals by the Department of Justice for antitrust reforms.[2] The growth of joint ventures has implications for both the production and utilization of

[2] An excellent survey of recent developments is contained in the *National Journal*, May 14, 1983, pp. 1000-1005.

information from federally funded research. Especially, these cooperative arrangements may increase the demand for information and thus put additional pressure on federal agencies to improve their information utilization activities. Moreover, it is uncertain to what degree firms will be able to share information in both their basic and applied research activities without violating antitrust laws.

Studies should be undertaken as to the degree to which (a) antitrust barriers exist to the sharing and use of information that would be in the public interest, (b) how these barriers might best be overcome, (c) how the growth of private joint ventures will affect the demand for information from federal agencies, and (d) how the information needs of these ventures can best be accommodated, either by federal or private sector initiatives.

Tax Considerations

Past studies of information policies have noted two basic ways to improve the utilization of information: (a) strengthening the supply side by encouraging improved data collection, evaluation, and user access, and (b) strengthening the demand side.

One way to strengthen the demand side is to provide tax credits or other tax advantages. Until 1981, federal law did not provide a tax credit specifically for research or experimental expenditures. However, the Economic Recovery Act of 1981 provides that a taxpayer's investment in machinery and equipment employed in research or other experimental activities is eligible for the investment tax credit to the same extent as investment in other business activities. In addition, monetary support granted to research institutions producing nonproprietary information likewise receives a tax credit.

How effective tax credits will be in stimulating user demand for information remains to be seen. Study is needed of the likely effect of tax credits and other tax provisions on the demand for information (whether supplied by federal or other sources). Such tax policies might have either a trivial or significant effect, in comparison with changing domestic and foreign market conditions, for the output of private-sector R&D activities--and hence on the demand for information from federally funded and other sources.

Patent Policy

Amendments to the patent and trademark laws in 1981 replaced a melange of 26 different agency policies on vesting of patent rights in government-funded research with "a single, uniform national policy designed to cut down on bureaucracy and encourage private industry to utilize government funded inventions through the commitment of the risk capital necessary to develop such inventions to the point of commercial application" (U.S. Code, *Congressional and Administrative News*, Vol. 5, 1980, p. 6462). Ownership of patent rights in government-funded research by nonprofit or small-business contractors now vests in these organizations. Other contractors are given exclusive licenses, under conditions specified in the amendments, giving them proprietary rights previously unavailable. These incentives are expected to improve the incentive of private sector firms to acquire and apply the results of federally funded R&D.

Like the issues of copyright discussed above, issues arise about the extent to which proprietary rights to information improve or degrade knowledge transfer from federally funded research activities. On the one hand, the scope of publicly available information bases (and perhaps their usefulness) is reduced because they do not include proprietary material. On the other hand, the expansion of exclusive rights may encourage the expansion of inventive activity, and thus the utility of information that, though developed through the private marketplace, results in products that serve the public interest. Study is needed of the implications of these patent amendments for information policy and of other changes that may be needed in patent laws.

COMPARATIVE NATIONAL POLICIES AND TRANSBORDER INFORMATION

Examination of information policies in other industrialized countries could provide valuable insight into the opportunities for improvements in the United States. Quality assurance mechanisms used elsewhere might provide guidance for recognizing opportunities and avoiding problems in the quest for better-evaluated information. Similarly, valuable insight might be derived from examinations of ways in which foreign organizations interpret and exploit the utility of the open scientific and technical literature.

Two frequently voiced concerns are that (a) foreign firms make better use of information from U.S. research activities than do domestic firms; and (b) information exchange is largely a one-way street--foreign firms gain more from American-generated information than do American firms from foreign sources. These concerns are based on comparisons of patent application data in Japan and the U.S. and on the erosion of the competitive edge of domestic firms in high-technology industries.

Foreign countries gain more from the United States than we do from them if for no other reason than that more basic research is done in the United States than in any other single country. However, language problems also create an asymmetry in information use; for instance, more Japanese engineers and scientists have a working knowledge of English than their American counterparts have of the Japanese language. In addition, management structures and processes within Japanese organizations are believed to promote industrial application of R&D innovations while interorganizational collaboration is thought to promote information resource sharing. But whether foreign firms in fact are better able to utilize information than American corporations is less clear. The advantages enjoyed by foreign firms may stem from a number of factors, such as low-cost labor and, more recently, a very strong dollar exchange rate. Study is needed of the extent to which advantages also accrue from better usage of information, including mechanisms for using knowledge transfer to encourage industrial innovation. International study might provide valuable insights for the generation of viable policy alternatives for the knowledge transfer process.

APPENDIX B.
A HISTORY OF FEDERAL INFORMATION POLICIES[1]

The federal government to date has not seen a need to develop a coordinated agency-wide system for disseminating scientific and technical information. Instead, federal involvement in this area has been characterized by disparate policy actions that generally reflect changes in society's attitudes about science, technology, or information. These actions have often been initiated by executive branch agencies; sometimes they have been confirmed by broader administrative and legislative mandates. They have always been tied to budgetary considerations.

The history of these policies reveals two basic characteristics: First, although opinions regarding the optimal level of federal commitment have varied, it has become axiomatic that scientific and technical information is sufficiently valuable to justify some federal role in its production and transfer. Second, the primary justification for federal support has rested in the potential for converting scientific and technical information into improvements in the nation's welfare. For this reason, priorities for disseminating scientific and technological information have usually mirrored national priorities (new weapons systems, space, exploration, better crops) and reflected estimates of who uses the information best (scientists in research settings, physicians in hospitals, engineers in industry).

The dimensions of information transfer--availability, quality assurance, and responsiveness to the user environment--have had varying degrees of federal attention. In response to the post-1945 information explosion, federal dissemination policies concentrated on establishing and supporting tools to promote the availability of information. Essential as these efforts have been in preventing the loss of valuable research findings, they have not proved effective as knowledge transfer needed mechanism.

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[1]This summary draws heavily on the following sources: Burton W. Atkinson (1978); Rossmassler and Watson (1980); and NATO (1983).

There has been a longstanding awareness that evaluation must be an integral part of packaging information for users' needs. The Weinberg report (1969) underscores the scientific importance of compacting, reviewing, and interpreting the literature, both for basic research progress and for more specialized application. The evaluation issue is emphasized in relation to technical reports because, although they are significant output vehicles for federal research, they lack an established peer review process. Consequent such products are often not perceived by the scientific and technical community as prestigious sources of information. The challenge of creating high-quality, high-utility information by means of data evaluation efforts has been taken up by modestly funded federal programs, as well as by international coordinating agencies, professional societies, and commercial publishers--with limited success as yet (Carter, 1980; Westbrook in AGARD, 1983a).

In the last 15 years, many programs for disseminating scientific and technological information have begun to address the difficulties involved in transferring knowledge to target audiences. Studies have recommended analyzing communication among scientists and engineers to integrate formal information channels with informal communication patterns (SATCOM, 1969). Administrators of scientific research have come to understand that transferring knowledge effectively to users requires tailoring technical information to meet the users' needs.

In the remainder of this section, we review representative policy accomplishments, failures, and opportunities arising from federal activities relating to information availability, quality assurance, and responsiveness to the user environment. Milestones in the history of information policy are summarized in Appendix C.

AVAILABILITY

The federal government provides the nation's major funder of R&D. In 1982, total U.S. R&D expenditures were estimated at $77.3 billion, and federal expenditures at $38.7 billion--close to 50 percent (Bureau of the Census, 1982).

Traditionally, the federal investment in transferring scientific and technical information (STI) focuses on its production and use. Of the $6.4 billion the federal government expends annually on STI, federal and nonfederal information organizations receive only about 25 percent. The bulk goes to support the use and authorship of information (King, 1977; Science Indicators, 1980). The federal government supported authorship accounted for 38 percent of all STI authorship in 1975. Only 4 percent of 1975's federal STI costs went to publishing, and only 1 percent to abstracting and indexing. King's research shows that each federally funded R&D project produces, on average: 1.98 articles in U.S. journals, 1.56 research reports, 1.11 other written products (books, monographs, nonjournal articles), and 3.03 oral presentations in the United States (King, McDonald, and Roderer, 1981, p. 259).

Tools for Disseminating Federally Funded Research

Support for nonfederal dissemination of federally funded research has a long tradition. In 1961, the Federal Council for Science and Technology established a governmentwide policy of including page charges to journals in federal contracts and grants (Atkinson, 1978). This page charge policy provides critical support to many journals.[2]

In addition to disseminating research results through journal and book publishers, the federal government established the technical report as another primary outlet for research results. Although government technical reports began in the 1800s, their recent proliferation is tied to the appearance of mission agencies in the 1950s and 1960s. In terms of providing comprehensive information, technical reports have the advantage of no size limits. Scientists and engineers often use them to include full details on experimental design and data output, particularly since they constitute the formal records of projects.

[2]Current draft regulations by Congress's Joint Committee on Printing (JCP) put pressure on this system as evasions of the depository library laws and request funding agencies to prepare an annual waiver request to the JCP listing titles of the articles and journals and total payments (U.S. Congress, Joint Committee on Printing, 1983).

Technical report production has placed new demands on the federal information system. Large federal information clearinghouses were established in the 1950s to archive, index, abstract, and disseminate technical reports. Among the most prominent of these is the National Technical Information Service (NTIS), begun in 1945 as the Publications Board to collect World War II documents captured from the enemy and disseminate them to industry. By 1950, Congress had converted the Board into the Office of Technical Services with responsibility for disseminating federally funded research results. In 1971, the newly structured NTIS became a national source for unclassified federal scientific and technical output in a variety of forms, including computer software, technology licensing, and data tapes.

These central clearinghouses and depositories have been hampered in their archival roles by the erratic compliance of contributing agencies. For example, in 1976, the National Science Foundation (NSF) issued a Staff Memorandum requesting its directorates to forward research output to NTIS. Compliance with this directive has been incomplete, with the bulk of NSF/NTIS reports coming from only two directorates (Sanchez et al., 1981). Without strict compliance among government agencies, material can be lost permanently--particularly report literature for which alternative archives such as libraries do not usually exist.

Support for other document delivery systems has followed more traditional mechanisms. Currently the federal government funds three national libraries, 3000 libraries in the federal network, several statistical centers, and many other activities (King, 1977). The Library of Congress has supported the development of library networks by sharing cataloging information and an active interlibrary loan system.

Mission-oriented research agencies such as the Atomic Energy Commission (AEC, now part of the Department of Energy or DOE), the National Aeronautics and Space Administration (NASA), and the National Institutes of Health (NIH) have also developed services to meet the multidisciplinary information needs of their staff and contractors. They established abstracting, indexing, and document delivery services for journal articles, books, dissertations, nontechnical government publications, conference proceedings, and international sources. Often

using private sector contractors, they designed advanced computerized information systems, thereby giving federal information systems a leadership role in advancing electronic information retrieval.

Indexing and Abstracting

Scientists conducting basic research traditionally relied on major journals and abstracting and indexing tools produced by professional societies. With the information explosion, many of these societies could not keep up with the literature's growth. From 1958 to 1976, NSF's Office of Science Information Services (OSIS) underwrote technological experiments and automation programs by the American Chemical Society (ACS), the American Institute of Physics, the American Psychological Association, the American Geological Institute, and other organizations. By 1974, NSF funding for these programs declined, but most of the programs and services continued to operate effectively.[3]

These automation efforts usually led to the creation of machine-readable databases. With the appearance of commercial online search services, such as Dialog, BRS, and SDC, these databases became online files paying royalties to the professional societies producing them (Atkinson, 1978).

Reassessment of the Government's Role

Reexaminations of the government's role as an information provider have been widespread in the 1980s, but conflicts between policies emphasizing information availability and others emphasizing restriction of output for trade protection and efficiency also have a long history. In 1969, the Department of Defense established a schedule of user charges for its Information Analysis Centers. AEC and NASA soon began to charge for microfiche and other services. NTIS has long supported itself under a full-cost-recovery program with a special revenue fund from its sales. Charging for federal information services has been given more support by the Office of Management and Budget pressures on many government agencies to recover the costs of their services from users.

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[3] In 1976, the OSIS responsibilities were transferred to the Office of Science and Technology Policy in the White House.

Many government information operations have been left in a dangerous quandary by conflict between policies promoting information availability and directives to economize. The lack of coordinated policy mechanisms to represent the special interests of scientific and technical information could pose a real threat to the continuity of its flow.

Summary

Since World War II, the federal government has sponsored the publication of federally funded research, supported secondary services to document and retrieve the published scientific and technical literature, and funded information science and the development of new information technologies. Federal contributions, in collaboration with the private sector, have substantially accomplished the objective of coping with the information explosion. A full range of primary sources--journals, books, technical reports--that document research findings are being produced. Secondary sources--indexes, abstracts, newsletters, trade journals--now cover most major areas of science and have proven themselves capable of expanding quickly to cover new fields. Advanced information services--bibliographic databases, online searching, full-text document delivery, information brokers--are emerging from the private sector with some government support, providing worldwide access to the scientific and technical literature. However, recent budgetary constraints have created apprehension about continued federal support for established services. The lack of coordinated policies to represent the interests of the scientific and technical community in these debates increases the concern of those committed to the integrity of this body of information.

QUALITY ASSURANCE

Although the federal government has made available enormous amounts of information, the quality of what reaches users often leaves much to be desired. For more than twenty years, critics have noted the lack of high quality, well-evaluated, and useful information from federal research efforts. As the Weinberg report stated in 1969: "We shall

cope with the information explosion, in the long-run, only if some scientists and engineers are prepared to commit themselves deeply to the job of sifting, reviewing, and synthesizing information: i.e., to handling information with sophistication and meaning, not merely mechanically. Such scientists must create new science, not just shuffle documents. Their activities of reviewing, writing books, criticizing, and synthesizing are as much a part of science as is traditional research." The issue has not changed. Fifteen years later, Branscomb (1983, p. 11) observed, "Funding of research to produce generally useful knowledge carries with it a responsibility, not only to ensure publication of results but also their evaluation and preparation in a form suitable for application..."

The issue of quality assurance in the scientific and technical literature has generally been addressed in three ways: (1) the peer review process, (2) published compilations or reviews, and (3) critical evaluation programs and information analysis centers for some physical and chemical data. (The discriminative powers of advanced information retrieval services and databases will be covered in the section on User Responsiv.)

Peer Review

Peer review through the editorial procedures of scientific and technical journals offers the most generally applied and available quality control measure. Federal support for traditional scientific dissemination sources, particularly the primary journals, has had the effect of applying peer review to federal R&D products. Further, some agencies (e.g., NSF, NIH) encourage publication of research results in reviewed literature rather than in technical reports. Of the journal articles submitted in a year, about 44 percent are rejected. About 28 percent are resubmitted to another journal, and 16 percent are dropped (King, McDonald, and Roderer, 1981). As the proliferation of journal titles indicates, the chances are good that an article rejected by one journal will be accepted by another.

The other major output device for federal research is the technical report. Report literature has no generally established review procedure. For this reason, among others, the technical reports lack a

reputation for reliability among most basic researchers. On the other hand, applied researchers and engineers, who are more familiar with them, find their detail and currency very desirable.

Passman (1969) points out that technical reports may in fact receive more critical review than is generally recognized. Research proposals have undergone peer reviews, and the researchers' qualifications to perform the research have been scrutinized before the project begins. Many federal agencies, particularly those supporting basic research like the National Science Foundation and the National Institutes of Health, have long established peer review programs to select research projects. Throughout the course of the project, researchers may consult frequently with government liaisons, other groups active in the field, and even advisory groups. When the project is completed, the final technical report may be reviewed and edited by coworkers within the research organization, often including professional editors and management review teams.

Critical Data Evaluation

Another dimension of the quality assurance picture involves the critical evaluation of data by experienced scientists. The objective of such an evaluation is to provide authoritative data that can be used with confidence by a well-defined community.

There are many different approaches to classifying data. For example, the International Council of Scientific Unions' Committee on Data for Science and Technology (CODATA) breaks data into three broad categories with numerous subdivisions: repeatable measurements on well-defined systems, observational data on environmental systems, and statistical data on population and economic characteristics (Lide, 1983). Classification could also follow use patterns: data used widely, data generated and used only by specialists in the same field, and data used by scientists in a limited number of related disciplines (Watson, 1983).

Evaluation programs vary depending on the type of data collected and the users' needs among other things. However, most programs have four things in common: (1) data collection (e.g., satellite images, social surveys, literature searches), (2) data examination (e.g.,

experimental techniques, theoretical/calculational processing, measures and standards used), (3) critical evaluation by experts for the best values (data evaluation centers, critical review panels, individual collectors), and (4) dissemination to the user in a useful, well-documented form (e.g., handbooks, electronic databases, integrated design analysis programs). Most evaluation projects require expert staff and labor-intensive, meticulous work.

Long-term federal support for critically evaluated or reference data started with the creation of the International Critical Tables project in 1919, administered by the National Research Council (NRC). In 1957, the NRC established what is now the Numerical Data Advisory Board (NDAB), which monitors national and international critical data programs, represents the United States on CODATA, and provides guidance to the National Bureau of Standards (NBS) in its administration of the present critical tables program. The other major federal effort in critically evaluated data is the National Standard Reference Data System (NSRDS), managed by NBS' Office of Standard Reference Data (OSRD). NSRDS coordinates reference activities of various organizations and establishes standards for quality and methodology. It also invests funds to establish data centers and compilation projects, but only when it identifies gaps that other agencies do not fill.

Information analysis centers, established in the 1960s under the impetus of the Weinberg report, usually provide another source for evaluated data. Funded by government or industry, examples of such centers include Battelle Memorial Institute's centers, the Applied Physics Laboratory at Johns Hopkins University, the Infrared Research Information Service at the University of Michigan, and the Electronic Properties Information Center at Purdue University. However, only some of these centers are still involved in rigorous critical evaluation despite the fact that users valued the centers' evaluation efforts more highly than their technology transfer activities (Corridore, 1976).

Other government agencies have programs for collecting and evaluating data: The Government-Industry Data Exchange Program (GIDEP) shares technical data on the reliability of parts, components, and material (Richards, 1977); Brookhaven National Laboratory's National Nuclear Data Center coordinates a large international collection of

atomic chain data; the National Library of Medicine's Toxicological Data Bank uses a network of scientists to review the toxicological literature and extract and evaluate key data; and the Laboratory Animal Data Bank records detailed information on the strain characteristics of control animals.

Summary

Despite a long history of complaints about the quality of data from federal projects that reach users, efforts to improve quality controls have had relatively little effect. Technical reports rarely receive review, although implicit review processes may be in place. Data evaluation programs, which dominate the literature, receive little funding or leadership support. Although computer-based technology promises new tools for providing greater amounts of evaluated information, start-up efforts and costs have prevented their more extensive employment for this purpose.

USER-RESPONSIVENESS

In the face of the postwar information explosion, federal policymakers attempted to reach scientists, engineers, and industry by establishing technical-report delivery systems, supporting the creation of technologically advanced indexing and abstracting systems, and offering low-cost access. However, it soon became apparent that formal information channels could not by themselves meet the needs of users. The new tools were not readily incorporated into ongoing work. "Another aspect of the operation of the communication network which we need to understand more fully is the sluggishness with which individual work habits respond to new opportunities or challenges" (SATCOM, 1969, p.103).

As a first step toward helping users to search the masses of primary literature for specific data, a number of *data flagging* or *data tagging* projects have been attempted. *Data flagging* notes the presence of primary numeric data, while *data tagging* offers a description of it. These numerical indexing attempts have not succeeded in attracting continuous support and integration into information services. Experiments with private sector information services such as Chemical

Abstracts, with journal publishers such as the American Institute of Physics, and with federal information services such as NASA have not proved fruitful. The cost of data tagging--equivalent to another subject indexing (Murdoch, 1980)--has not been seen as justified by the market. Proposals to change the structure of federal research reports to include data tags have also failed. Several professional societies, for example, the ACS and the AIP, have established data repositories for authors of articles to store the details of their research findings. Poorly indexed and advertised, these depositories received minimal use (Carter, 1980).

In attempts to get information into users' hands more quickly, agencies began to support user-based information networks. In 1961, the National Institutes of Health inaugurated Information Exchange Groups to provide a central clearinghouse for exchanges of correspondence and commentaries with colleagues in advance of journal publication. By 1966, the system was sending out 1.5 million copies of preprints. It was so successful that it aroused the anger of established publishers, support was withdrawn, and the groups dissolved (Passman, 1969, p. 71). The advent of electronic publishing has inspired a revival of this approach.

Systems such as the above still built on formal information tools. Almost as soon as they began, the major government information services inaugurated programs to reach out to industry and later to the scientific community as well. Most federal agencies had chartered mandates to transmit needed information to their constituent communities, particularly information that resulted from federally funded research.

With the development of automated information handling techniques, most of the major clearinghouses offered a varied package of specialized services by the early 1960s. These packages included continuing current bibliographies in topical areas, searches on demand, current-awareness programs, technical notes alerting researchers to major new findings, and special abstracts for new research areas. For example, in 1965, the Office of Education established the Educational Resources Information Center (ERIC), which employs a network of university-based clearinghouses to collect and disseminate education literature. In

1966, NASA began working with the Lockheed Corporation to design an online interactive search service called RECON. By 1969, the system was operating with seven online stations and a library of a half million citations. The AEC and its successor, the Department of Energy, devised their own versions of the same system. The National Library of Medicine (NLM) contracted with Systems Development Corporation (SDC) to design online search software to provide access to their MEDLARS (Medical Literature Analysis and Retrieval System). Many of these systems became the bases for commercial ventures using software originally developed under government contract. Most clearinghouses continue these services today. However, recent pressure on the budgets of federal information services and programs to reduce duplication have moved many agencies to use central interagency clearinghouses--particularly the National Technical Information Service--to deliver documents to the public. Centralization can achieve economies, but it can also diminish the communication between the research agency and its technical community.

New Technology

With the arrival in the 1970s of government and commercial online search services, new discriminatory capabilities became available. More sophisticated information retrieval was offered, at least in principle, by the ability to design search strategies more tailored to individual user needs and by using the full information content of the index or abstract record. However, most databases were the result of automating printed services. Few were redesigned to exploit the capabilities of the new technology. In addition, the creators of the online systems faced the problem of integrating information from different databases that used different standards and identification schemes.

In addition to the expense and complexity of online searching of databanks, users complain that it is difficult to assess the reliability of the data without sufficient documentation of the original source (Rossmassler and Watson, 1980).

Full-text document delivery promises new avenues for locating data. In 1983, BRS Inc., an online search service, added all eighteen of the American Chemical Society's journals. They have also begun to add the full text of biomedical and psychological textbooks, e.g., *Gray's*

Anatomy and *Mental Measurements Yearbook.* A major software revision announced by Dialog, the largest bibliographic search service, will include full-text capabilities. Recent experiments indicate up to 60 percent success in locating articles by specific data needs through full-text searching techniques (Rossmassler and Watson, 1980). However, these approaches reach only a handful of the sources, do not evaluate the quality of the data found, and are at present rather costly.

Although online search services were originally meant to serve the information user directly, intermediaries continue to predominate in online searching. However, with the rise of microcomputers and distributed data processing in this decade, opportunities for end-user searching of online files grow. New software, such as Franklin Institute's OL'SAM and ISI's Searchmate, may encourage direct user access to bibliographic and numeric databases.

Directed Information Transfer

In the 1970s, major legislation began to include provisions for directed information transfer. The National Environmental Policy Act of 1969 took a significant step toward improving access to technical information by requiring that federal agencies prepare Environmental Impact Statements and publicize the documents available for public scrutiny. Agencies were not to wait for requests but were to contact organizations with environmental interests to apprise them of potential negative effects. The Energy Reorganization Act of 1974 mandated the collection, preparation, and dissemination of information on energy alternatives "to provide the full exchange of ideas and criticism that is essential to...public understanding."

Incorporating Human Information Networks and Change Agents

In the 1960s, high-level commission reports (Weinberg, 1969, SATCOM, 1969) began to recommend that information systems conform to the way scientists and engineers really communicated, as established through research. That meant heavier reliance on interactive and informal processes of communication rather than document delivery. As the Weinberg report observed, "...knowledgeable scientific interpreters who can collect relevant data, review a field and distill information in a

manner that goes to the heart of a technical area are more help to the overburdened specialist than is a mere pile of relevant documents" (Weinberg, 1969).

The Information Analysis Centers of the 1960s and 1970s, although still heavily reliant on formal publication of their evaluated data, also attempted to use technical professionals as technology transfer agents, hoping to build networks of communication. The high cost of these programs made them vulnerable to funding cuts. Ineffective marketing hampered their service to their target audience. User studies showed that handbook compilations of evaluated data were prized more than technology agent functions (Corridore, 1976).

Other mechanisms using change agents sprang up in the 1970s. Congress established the Office of Technology Assessment to review and analyze technical questions. The National Institute of Education's National Diffusion Network reviews educational research projects and then promotes in-service training to educators throughout the country (Neill). The Research Applied to National Needs (RANN) program began at NSF to target problems of national concern and coordinate their technical solution with the private sector. In 1974, NSF supported and coordinated the establishment of the Federal Laboratory Consortium, an informal organization of approximately 200 of the largest federal research laboratories. A key consortium practice was the support by each member laboratory of a technology transfer representative to keep the laboratory in touch with other research institutions and other federal, private, and public agencies. The goal of the group was to provide a framework for applying laboratory capabilities to national problems (Linsteadt, 1980). The Stevenson-Wydler Act of 1980 mandated such technology transfer agents for every laboratory, but funding has not been forthcoming (Gottlieb, 1982).

University-industry collaborative research programs began in the 1970s as an effort to transfer information by getting knowledge procedures and users together. These efforts have experienced a new surge in the 1980s, especially in high-technology areas, where research advances rapidly and foreign competition threatens. Declining university budgets and enrollments as well as industrial productivity concerns have encouraged these developments. NSF has a long tradition of promoting this type of venture with varying success.

Summary

Tailoring information to target audiences requires detailed knowledge of their institutional environment and of the way in which they typically use information. New advances in information technology may in principle improve the ability to communicate government funded research, but in fact institutional barriers and human behavior considerations still predominate. Changing behavior must be a long-term goal, and federal information policies have often lacked the direction, support, and leadership necessary to maintain continuity. Improving the utility of collected information through better technology, better access structures, enhancement of informal systems or a combination of factors is possible. However, the success of future efforts is likely to depend on the extent to which users themselves are involved in policy and system development instead of remaining the passive targets.

APPENDIX C. MILESTONES

INFORMATION POLICY MILESTONES	RELATED EVENTS
1945	
Publications Board established by executive order to collect and declassify WWII technical data for dissemination to industry.	
National Advisory Coommittee on Aeronautics initiated scientific reports to supplement scientific journals for dissemination of research results.	
1946	1946
Vannevar Bush called for establishment of National Science Foundation in *Science--The Endless Frontier.*	First all-electronic digital computer invented.
Information Center on Chemical-Biological Coordination established.	
National Research Council Committee on Line Spectra of the Elements established sponsoring atomic energy levels data project at National Bureau of Standards	
1947	1947
Atomic Energy Commission established Industrial Information branch.	Microwave radio relay system commercially operated between Boston and N.Y.
1950	1950
Law enacted establishing Office of Technical Services in Department of Commerce to serve as clearinghouse for federally sponsored research results	First automatically sequenced high-speed electronic digital computer introduced in U.S.
Passage of National Science Foundation Act.	
Berkner Report to State Department	

on science, foreign relations, and national flow of sci/tech information released.

Medical Science Information Exchange (MSIE) established in National Research Council to inventory current R&D in medicine.

1951

Armed Services Technical Information Agency established.

1951

First UNIVAC system delivered to Census Bureau.

1952

NSF established Office of Science Information.

National Research Council's Subcommittee on Physical Chemistry issued recommendations.

1953

NSF shifted Medical Science Information Exchange to Smithsonian, expanded scope to include biology and psychology and renamed it Bio-Sciences Information Exchange.

1954

Atomic Energy Act authorized AEC to make information available to U.S. industry and foreign countries under cooperative agreements.

1954

UNIVAC commercially available.

1955

Gas Processors Association began Cooperative Industry Research program to improve data on basic thermodynamic properties of natural gas liquids.

1956

U.S. Armed Forces Medical Library became National Library of Medicine.

Creation of President's Science Advisory Committee and position of White House Science Advisor

1956

First voice trans-Atlantic telephone cable with underwater amplifiers.

1957

Information Center on Chemical-Biological Coordination discontinued.

National Research Council established Office of Critical Tables (later renamed the Numerical Data Advisory Board (NDAB)).

1958

National Defense Education Act created Science Information Council and Office of Science Information Service in NSF.

1958

Second-generation computers using solid state circuitry, stored programs, and user-oriented programming language.

1959

Federal Council for Science and Technology established.

Nasa launched its first active communications satellite, SCORE.

1960

Bio-Sciences Information Exchange became Smithsonian Science Information Exchange covering ongoing federally funded R&D projects plus some private research funding.

DOD established Mechanical Properties Data Center.

1960

NASA launched its first passive communications satellite, ECHO I.

American Institute of Chemical Engineers and American Petroleum Institute established the Design Institute for Physical Property Data at Pennsylvania State University.

1961

Federal Council for Science and Technology approved policy of including page charges by scientific and technical journals in contract and grant costs.

Committee on Scientific Information established in FCST.

1962

Office of Science and Technology created in Executive Office of President.

Library of Congress organized National Referral Center for Science and

1962

First live television programs relayed between America and Europe via Telstar I.

Depository Library Act enacted.

Technology to review, monitor, and offer coordinated access to federal R&D activities.

Scientific and Technical Communications in the Government (Crawford Report) recommended central agency to direct federal information policy and establishment of special units in R&D mission agencies to deal with sci/tech information.

NASA contracted with American Institute of Aeronautics and Astronautics to acquire all nonfederal published literature in aeronautics and astronautics and to catalog, index, and abstract it.

1963

Release of *Science, Government and Information: The Responsibilities of the Technical Community and the Government in the Transfer of Information* (Weinberg Report) recommended establishment of information analysis centers to evlauate research data and facilitate transfer of information.

National Bureau of Standards established National Standard Reference Data System to improve critically evaluated data.

1964

Federal Council on Science and Technology's Committee on Scientific Information renamed Committee on Scientific and Technical Information (COSATI).

Office of Technical Service became Clearinghouse for Federal Scientific and Technical Information (CFSTI).

Responsibility for coordination of federal sci/tech information activities transferred from NSF to Office of Science and Technology in White House.

1964

Federal Property and Administrative Services Act of 1949 amended (Brooks Act); directed General Services Administration to coordinate and provide for federal computer procurement.

Chemical Abstracts Services began a systematic registration system for all chemical compounds (CAS Registry Numbers).

1965

OECD established Scientific and Technical Information Policy Group.

Medical Library Assistance Act authorized creation of a regional medical library network by the National Library of Medicine

Office of Education established Educational Resources Information Centers (ERIC).

Federal Library Committee organized.

NSF, DOD, NLM initiated special funding to develop advanced information services by professional societies' abstracting and indexing services.

Multiyear contract let to American Chemical Society for automating Chemical Abstracts by National Science Foundation.

Lister Hill Center for Biomedical Communications inaugurated at NLM to support pioneer work in application of computer and communications technology to biomedical-information transfer.

1965

Third-generation computers introduced, using integrated circuits, miniaturization, system logic improvements, and higher speeds.

Communications Satellite Corporation launched Early Bird, first in its Intelsat international satellite communications system.

1966

First pilot Federal Information Center opened in Atlanta.

International Council of Scientific Unions estabished Committee on Data for Science and Technology (CODATA).

Rare Earth Information Center established by rare earth industry.

1967

NLM established Toxicology Information Program.

AEC and NASA inaugurated joint program publishing Tech Briefs to reach

smaller firms with research results.

1968

Congress passed Standard Reference Data Act.

1968

Carterfone Decision--FCC opened terminal devices for connection to the telephone system.

1969

National Academy of Science/National Academy of Engineering's Committee on Scientific and Technical Communication (SATCOM) produced final report.

DOD required Information Analysis Centers to charge for products and services.

EPA-NIH Chemical Information System (CIS) established as collaborative international effort to collect organic chemical databases for online networking and manipulation.

1969

MCI Decision--FCC authorized provision of private line microwave services by carriers other than established common carriers.

1970

CFSTI became National Technical Information Service (NTIS) with clearinghouse functions expanded to include business and statistical information.

U.S. National Commission on Libraries and Information Services created.

National Oceanographic and Atmospheric Agency (NOAA) established Environmental Data Service.

1971

NLM and Oak Ridge National Laboratory initiate Toxicology Information Response Center.

1971

Permanent charter for International Telecommunications Satellite Corp. (INTELSAT) signed by 54 nations.

1972

ARPANET, experimental national network of computers, became operational.

1972

First domestic communication satellite went into orbit.

1973

NBS, American Chemical Society, and American Institute of Physics began publication of the Journal of Physical and Chemical Reference Data.

1973

Fluid Properties Research Inc. established at Oklahoma State University by international group of companies to provide organic chemical properties data.

1974

Federal Laboratory Consortium established to link in-house federal research results to civilian sector.

Office of Education established National Diffusion Network to evaluate and promote dissemination of exemplary programs to school districts.

1974

Privacy Act of 1974 enacted.

1975

Freedom of Information Act amendments enacted.

Low-cost, limited-capacity micro-computers introduced.

1976

NSF discontinued Office of Science Information Services and created Division of Science Information in Directorate for Scientific, Technological, and International Affairs, refocusing activities to support information science research.

1976

Computer Software Copyright Act enacted.

1978

NSF Division of Science Information restricts support for direct dissemination of sci/tech information, placing responsibility on research directorates.

National Telecommunications and Information Administration formed in Department of Commerce.

1978

Federal Information Centers Act enacted establishing national network of FICs.

1980

1980

Center for Utilization of Federal Technology established in NTIS by Stevenson-Wydler Technology Innovation Act to provide short technology assessment reports on projects with potential use by the private sector or local governments.

Integrated Library System offered for sale to library community by NTIS after two years' development by Lister Hill Center.

Laboratory Animal DataBank available online through NLM and Battelle-Columbus Laboratories.

1980

Administration budget cuts eliminated several statistical collections--Multiple Jobholding Survey (BLS), Directory of Union Membership (BLS), Student Residence and Migration Survey (NCES), Intercensal Population Estimates (Census).

1982

NLM Toxicology Information Program initiates Hazardous Substances Information Services to provide relevant toxicological information to health officials.

1983

Joint Committee on Printing draft regulations redefined government publication to include electronic formats as well as print.

Superindex, master index to contents of scientific and technical handbooks, goes online commercially.

Smithsonian Science Information Exchange discontinued.

Paperwork Reduction Act enacted establishing OMB as agency to oversee federal data collection procedures.

1983

OMB revises Circular A-76 requiring agencies to contract out a broad range of administrative activities.

1984

AT&T divested itself of Bell System

regional phone companies.

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